City of Avondale

FINAL Report

Water Resource Master Plan

MAY 2010

Registered Professional Engineer (Civil)
CERTIFICATE NO. 22684
TIMOTHY FRANCIS
Date Signed 5/3/10
ARIZONA, U.S.A.
Expires 12/31/11

0864-025

Solutions for Life

MALCOLM PIRNIE

MALCOLM PIRNIE

INDEPENDENT ENVIRONMENTAL ENGINEERS, SCIENTISTS AND CONSULTANTS

Malcolm Pirnie, Inc.
4646 East Van Buren Street, Suite 400
Phoenix, Arizona 85008
T: 602.241.1770 F: 602.231.0131
www.pirnie.com

May 3, 2010

Michael N. Smith, P.E., Water Resources CIP Engineer
Water Resources Department
City of Avondale
399 East Lower Buckeye Road, Suite 100
Avondale, AZ 85323

Re: *Water Resource Master Plan*
Final Report

Dear Mr. Smith:

Malcolm Pirnie, Inc., in association with Replenishment Services, is pleased to submit the *Water Resource Master Plan* Final Report. The master plan presents a recommended future water supply strategy and water resources management strategies that will support future City growth and help to maintain the City's Designation of Assured Water Supply with the Arizona Department of Water Resources. Two useful planning tools were developed as part of the *Water Resource Master Plan*: a geographical information system (GIS) tool that will allow the City to evaluate any land use development scenario it wishes in developing water demand projections, and a groundwater model that will allow the City to determine the long-term impacts of alternative well locations and pumping operations on local groundwater levels and movement.

We sincerely appreciate the assistance and guidance provided by the City's Water Resources Department during preparation of the *Water Resource Master Plan*, and we look forward to continuing our working relationship in the future.

Very truly yours,

MALCOLM PIRNIE, INC.

Timothy Francis, P.E.
Senior Associate
Project Manager
Board Certified Environmental Engineer

Enclosures

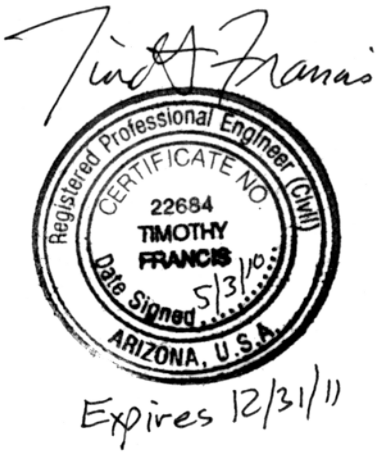
0864-025

City of Avondale, Arizona

399 East Lower Buckeye Road • Suite 100 • Avondale, AZ 85323

Water Resource Master Plan

May 2010



Report Prepared By:

Malcolm Pirnie, Inc.

4646 East Van Buren St.
Suite 400
Phoenix, AZ 85008

0864-025

MALCOLM PIRNIE

Registered Professional Engineer (Civil)
CERTIFICATE NO. 22684
TIMOTHY FRANCIS
Date Signed 5/3/10
ARIZONA, U.S.A.
Expires 12/31/11

Contents

Abbreviations/Acronyms vii

Executive Summary ES-1

1. Introduction 1-1

1.1. Background ... 1-1
1.2. Project Purpose and Scope ... 1-1
1.3. Study Area ... 1-2

2. Regulatory and Institutional Framework 2-1

2.1. Groundwater Management Act ... 2-1
2.1.1. Assured Water Supply Designation ... 2-2
2.1.2. Groundwater Rights ... 2-4
2.1.3. Service Area Rights ... 2-5
2.1.4. Third Management Plan ... 2-5
2.1.5. Fourth Management Plan ... 2-6
2.2. Central Arizona Groundwater Replenishment District ... 2-7
2.3. Underground Storage and Savings ... 2-8
2.3.1. Recharge ... 2-8
2.3.2. Storage and Recovery ... 2-8
2.3.3. Exchanges ... 2-9
2.4. Water Transfer Legislation ... 2-10
2.5. Central Arizona Project Subcontract ... 2-10
2.5.1. Water Delivery Subcontracts ... 2-10
2.5.2. Direct Underground Water Storage Facility Contracts ... 2-11
2.6. Salt River Project ... 2-11
2.6.1. Water Delivery and Use Agreement ... 2-11
2.6.2. Water Transportation Agreement ... 2-12
2.6.3. New River Agua Fria River Underground Storage Project Agreement ... 2-13
2.6.4. Paired Well Agreement ... 2-13
2.7. City Programs ... 2-14
2.7.1. Ordinances ... 2-14
2.7.2. Water Conservation Program ... 2-15
2.8. Well Spacing and Well Impact Rules ... 2-15

2.9. Water Reuse Regulations 2-15
2.10. Safe Drinking Water Act 2-17

3. Existing Water Supplies 3-1

3.1. Existing Designation of Assured Water Supply 3-1
3.1.1. Salt River Project 3-2
3.1.2. Central Arizona Project 3-3
3.1.3. Groundwater 3-3
3.1.4. CAGRD 3-4
3.2. Application for Re-designation of Assured Water Supply 3-4

4. Water Supply System and Water Quality 4-1

4.1. Service Providers 4-1
4.1.1. Water Service Providers 4-1
4.1.2. Wastewater Service Providers 4-1
4.2. Existing Water Infrastructure 4-4
4.2.1. Groundwater Production Wells 4-4
4.2.2. Reservoirs and Treatment Facilities 4-4
4.2.3. Water Reclamation Facilities 4-7
4.2.4. Recharge Facilities 4-7
4.3. Water Quality 4-8
4.3.1. Groundwater 4-8
4.3.2. Surface Water 4-10
4.3.3. Reclaimed Water 4-10

5. Future Water Resource Planning Considerations 5-1

5.1. Potential Additional Water Supplies 5-1
5.1.1. SRP Allotments 5-1
5.1.2. Groundwater from Buckeye/St. Johns Waterlogged Areas 5-2
5.1.3. Indian Lease/Settlement Water 5-2
5.1.4. Reclaimed Water 5-3
5.1.5. Reallocation of CAP Municipal and Industrial Water 5-3
5.1.6. Non-Indian Agricultural CAP Water 5-3
5.1.7. Other CAP M&I Supplies 5-4
5.1.8. Access to Excess 5-4
5.1.9. ADD Water 5-5
5.1.10. Outlook for Additional Future Water Supplies 5-5
5.2. Underground Storage and Recovery 5-6
5.2.1. Available Storage Capacity 5-6
5.2.2. Groundwater Quality Considerations 5-6
5.2.3. Storage Capacity Considerations 5-7
5.2.4. Potential Future ADWR Assured Water Supply Policies 5-7
5.3. Central Arizona Groundwater Replenishment District 5-8
5.3.1. City of Avondale Membership 5-8
5.3.2. Potential Direct Delivery Memberships 5-9
5.4. Water Conservation Program 5-10
5.5. Water Reclamation and Reuse 5-11
5.5.1. Previous Water Reuse Planning 5-11
5.5.2. Water Reuse Considerations for Water Resource Master Plan 5-12

5.5.3. Reclaimed Water Quality Considerations 5-13

5.6. Direct Use of Surface Water Supplies 5-14
5.6.1. Previous Surface Water Treatment Planning 5-14
5.6.2. Water Treatment Plant Considerations 5-15
5.6.3. Water Quality 5-17
5.6.4. Surface Water Treatment Assumptions 5-17

5.7. Water Shortage Considerations 5-18
5.7.1. Groundwater 5-18
5.7.2. Reclaimed Water 5-18
5.7.3. Salt River Project Water 5-18
5.7.4. Central Arizona Project Water 5-19
5.7.5. Firming of SRP and CAP Water 5-19

5.8. Future Water Supplies 5-22

6. Water Resource Projections 6-1

6.1. Previous Water Planning 6-1
6.1.1. 2002 Water Resources and Water Infrastructure Master Plans 6-1
6.1.2. 2005 Wastewater Collection System Master Plan & Utility Systems Evaluation 6-3
6.1.3. 2009 Water System Model Update and Analysis 6-3

6.2. Current Planning Approach 6-4

6.3. Current Planning Framework 6-5
6.3.1. Land Use Classifications 6-5
6.3.2. Development of Land Use Map 6-7
6.3.3. Population and Growth Projections 6-10

6.4. Historical Water Use 6-11

6.5. Historical Wastewater Flows and Reclaimed Water Production 6-13

6.6. Water Demand and Wastewater Flow Factors 6-14
6.6.1. Water Demand Factors 6-14
6.6.2. Wastewater Flow Factors 6-16

6.7. Baseline Water Resource Projections 6-16
6.7.1. Projections for Study Area 6-16
6.7.2. Projections for Areas South of Estrella Mountains 6-17

7. Comparison of Water Demands and Supplies 7-1

7.1. Development Scenarios 7-1

7.2. Supply/Demand Assumptions 7-2

7.3. Baseline Scenario 7-3

7.4. High Growth Scenario 7-5

7.5. Low Growth Scenario 7-7

7.6. No State Route 801 Scenario 7-7

7.7. Water Supply Driven Scenario 7-9

7.8. Development Scenario for Water Resources Planning 7-13

8. Water Supply Alternatives and Evaluations 8-1

8.1. Identification of Alternatives 8-1

8.2. Preliminary Investigations 8-2
8.2.1. Prioritization of Existing Wells for Rehabilitation/Re-drilling 8-2
8.2.2. Production and Storage Requirements 8-3
8.2.3. Surface and Reclaimed Water Recharge 8-5
8.2.4. Favorable Groundwater Quality Areas 8-7
8.2.5. Conceptual Hydraulic Modeling 8-9
8.2.6. New Pressure Zone 8-9
8.3. Development of Alternatives 8-9
8.3.1. Alternative 1: Continue Building Wells (East of Dysart Road) 8-9
8.3.2. Alternative 2: Continue Building Wells (Around Avondale Recharge Facility) 8-11
8.3.3. Alternative 3: Continue Building Wells (Throughout Service Area) 8-11
8.3.4. Alternative 4: Build a Surface WTP (At Avondale Recharge Facility) 8-11
8.3.5. Alternative 5: Build a Surface WTP (Near 107th Avenue and Roosevelt Street) 8-11
8.4. Hydrogeologic Evaluation of Alternatives 8-16
8.4.1. Groundwater Model 8-16
8.4.2. Summary of Water Supply Alternative Simulations 8-16
8.5. Cost Evaluation of Alternatives 8-18
8.6. Matrix Evaluation of Alternatives 8-20
8.6.1. Decision Criteria 8-20
8.6.2. Decision Criteria Prioritization 8-23
8.6.3. Alternative Scoring 8-24
8.6.4. Alternative Rankings 8-24
8.7. Selected Future Water Supply Alternative 8-26

9. Conclusions and Recommendations 9-1

9.1. Significant Findings and Conclusions 9-1
9.1.1. Water Demands 9-1
9.1.2. Existing Water Supplies 9-1
9.1.3. Future Water Supplies 9-2
9.1.4. Water Demands vs. Supplies 9-2
9.1.5. Drought/Extreme Water Shortage Analysis 9-2
9.1.6. Water Supply Alternatives 9-3
9.2. Basis for Recommendations 9-3
9.3. Recommendations 9-4
9.3.1. Recommended Future Water Supply Strategy 9-4
9.3.2. Ongoing City Activities 9-4
9.3.3. Other Recommendations 9-6

10. References 10-1

Tables

Table 2-1: Drinking Water Regulation Applicability 2-19
Table 3-1: Existing Avondale Designation of AWS Approved Water Supplies 3-2
Table 3-2: Pledged Water Supplies for Re-designation 3-5

Table 4-1: Existing Production Wells 4-6
Table 4-2: Existing Reservoirs and Treatment Facilities 4-7
Table 4-3: Recharge Facilities Available to the City of Avondale 4-8
Table 4-4: Avondale Groundwater Quality 4-9
Table 4-5. Surface Water Quality (2004 through 2008) 4-11
Table 4-6. Reclaimed Water Quality (2004 through 2009) 4-12
Table 5-1: SRP and CAP Drought/Shortage Evaluation Summary 5-21
Table 5-2: Future Water Supplies 5-23
Table 6-1: Comparison of Previous Land Use Categories and Demand Factors 6-2
Table 6-2: Land Use Map Composition at Build-out 6-10
Table 6-3: Historical Water Production and Use 6-12
Table 6-4: Non-Revenue Water 6-13
Table 6-5: Historical Wastewater Flows and Reclaimed Water Production 6-14
Table 6-6: Comparison of Water Demand Factors 6-15
Table 6-7: Calibrated Water Demand Factors 6-16
Table 6-8: Calibrated Wastewater Flow Factors 6-17
Table 6-9: Baseline Projections by SRP On-Project and Off-Project Areas 6-18
Table 6-10: Baseline Projections by Service Area and Future Service Area Lands 6-18
Table 6-11: Baseline Water Demand Projections by Land Use Classification 6-19
Table 7-1: Baseline Scenario Growth Projections 7-3
Table 7-2: High Growth Scenario Growth Projections 7-5
Table 7-3: Low Growth Scenario Growth Projections 7-7
Table 7-4: No State Route 801 Scenario Growth Projections 7-9
Table 7-5: Water Supply Driven Scenario Growth Projections 7-11
Table 8-1: Predicted Drawdown at Contaminant Plumes 8-17
Table 8-2: Cost Comparison of Water Supply Alternatives 8-18
Table 8-3: Alternatives Decision Criteria Scoring 8-27

Figures

Figure 1-1: Municipal Planning Area and Study Area 1-3
Figure 1-2: SRP On-Project and Off-Project Areas 1-4
Figure 1-3: Service Area and Future Service Area Lands 1-5
Figure 4-1: Water Service Providers 4-2
Figure 4-2: Wastewater Service Providers 4-3
Figure 4-3: Water Resources Infrastructure 4-5
Figure 6-1: Land Use Map for City MPA 6-8
Figure 6-2: Land Use Map for Study Area 6-9
Figure 6-3: Comparison of Population Projections 6-11
Figure 6-4: Historical Water Production 6-12
Figure 7-1: Water Resource Scenario Development Growth Projections 7-2
Figure 7-2: Baseline Scenario Demand/Supply Comparison 7-4
Figure 7-3: High-Growth Scenario Demand/Supply Comparison 7-6
Figure 7-4: Low-Growth Scenario Demand/Supply Comparison 7-8
Figure 7-5: No State Route 801 Scenario Demand/Supply Comparison 7-10
Figure 7-6: Water Supply Scenario Demand/Supply Comparison 7-12
Figure 8-1: Continue to Build Wells: Required Production Phasing 8-4
Figure 8-2: Build a Surface WTP: Required Production Phasing 8-4
Figure 8-3: Continue to Build Wells: Water Balance 8-6
Figure 8-4: Build a Surface WTP: Water Balance 8-6
Figure 8-5: Groundwater Quality Favorability Map 8-8
Figure 8-6: Alternative 1: Continue Building Wells (East of Dysart Road) 8-10
Figure 8-7: Alternative 2: Continue Building Wells (Around Avondale Recharge Facility) 8-12

Figure 8-8: Alternative 3: Continue Building Wells (Throughout Service Area) 8-13
Figure 8-9: Alternative 4: Build a Surface WTP (At Avondale Recharge Facility)..... 8-14
Figure 8-10: Alternative 5: Build a Surface WTP (Near 107th Avenue and Roosevelt Street) ... 8-15
Figure 8-11: Cost Comparison of Water Supply Alternatives (No Additional Groundwater Treatment) 8-19
Figure 8-12: Cost Comparison of Water Supply Alternatives (25% Groundwater Treatment by Volume) 8-21
Figure 8-13: Cost Comparison of Water Supply Alternatives (75% Groundwater Treatment by Volume) 8-22
Figure 8-14: Decision Criteria Weights..... 8-25
Figure 8-15: Ranking of Water Supply Alternatives 8-25

Appendices

A. Referenced City Documents
B. Drought Analysis
C. Water Resource Demand Projection Tool
D. Hydrogeologic Evaluation
E. Alternative Calculations
F. Groundwater Flow Modeling

Abbreviations/Acronyms

A.R.S.	Arizona Revised Statutes
AAC	Arizona Administrative Code
ADD	Acquisition, Development, and Delivery
ADEQ	Arizona Department of Environmental Quality
ADWR	Arizona Department of Water Resources
AF	acre-feet
AFY	acre-feet per year
AMA	active management area
APP	aquifer protection permit
AWBA	Arizona Water Banking Authority
AWQS	aquifer water quality standards
AWS	Assured Water Supply
AWWA	American Water Works Association
AZPDES	Arizona Pollutant Discharge Elimination System
bgs	below ground surface
BOD_5	five-day biological oxygen demand
C	commercial (land use)
CAGRD	Central Arizona Groundwater Replenishment District
CAP	Central Arizona Project
CAWCD	Central Arizona Water Conservation District
City	City of Avondale
CPP	Continuing Planning Process
CSIF	Central Arizona Project/Salt River Project Interconnection Facility
DBP	disinfection by-product
E	employment (land use)
EDCs	endocrine disrupting compounds
FMDR	future medium density residential (land use)
FRCO	freeway commercial (land use)
GIS	geographic information system
gpad	gallons per acre per day
gpcd	gallons per capita per day
gpd/du	gallons per day per dwelling unit

HDR	high density residential (land use)
IOC	inorganic chemical
LAU	lower alluvial unit
LDR	low density residential (land use)
LPSCO	Litchfield Park Service Company
M&I	municipal and industrial
MAG	Maricopa Association of Governments
MAU	middle alluvial unit
MCL	maximum contaminant level
MDR	medium density residential (land use)
MDRE	medium density residential Estrella (land use)
MFR	multi-family residential (land use)
mg/L	milligrams per liter
mgd	million gallons per day
MHDR	medium-high density residential (land use)
MPA	municipal planning area
MU	mixed use (land use)
NA	not applicable
NAUSP	New River and Agua Fria River Underground Storage Project
NIA	Non-Indian Agricultural
NPCCP	Non-Per Capita Conservation Program
NPDES	National Pollutant Discharge Elimination System
OS-I	open space - irrigated (land use)
OS-NI	open space - non-irrigated (land use)
PF	public facilities (land use)
PGA	Phoenix/Goodyear Airport
PIR	Phoenix International Raceway
PPCPs	pharmaceuticals and personal care products
PWS	public water system
RID	Roosevelt Irrigation District
RLDR	rural low density residential (land use)
SDWA	Safe Drinking Water Act
SOC	synthetic organic chemical
SRP	Salt River Project

SRV	Salt River Valley
TAZ	Traffic Analysis Zone
TDS	total dissolved solids
TOC	total organic carbon
TSS	total suspended solids
UAU	upper alluvial unit
USACE	United States Army Corps of Engineers
USBR	United States Bureau of Reclamation
USEPA	United States Environmental Protection Agency
USGS	United States Geological Survey
VOC	volatile organic chemical
WDUA	Water Delivery and Use Agreement
WMAT	White Mountain Apache Tribe
WQARF	Water Quality Assurance Revolving Fund
WQMP	Water Quality Management Plan
WRF	water reclamation facility
WTP	water treatment plant
WWTP	Wastewater Treatment Plant

THIS PAGE INTENTIONALLY LEFT BLANK

Executive Summary

Abstract

The work conducted in this Water Resource Master Plan update, for the study area consisting of the City's Municipal Planning Area north of the Estrella Mountains, has found that the City's planned water supplies are sufficient to support existing and planned land uses through build-out. The City's available water supplies are projected to be sufficient to support planned future growth without relying on groundwater replenished by the Central Arizona Groundwater Replenishment District.

The City's future water supply strategy should be to continue to build wells. This strategy will be less costly than building a new surface water treatment plant and will be easier to fund, as construction of wells can be spread out and completed as demand increases dictate. However, because a surface water treatment plant may provide benefits in achieving future assured water supply designations and could alleviate the need to build additional recharge capacity, and given the inherent uncertainty for future groundwater treatment, the City should lock up a site now for a potential surface water treatment plant. This will preserve the City's future options should a treatment plant option become necessary due to regulatory, institutional, or water quality needs.

Introduction

The City of Avondale (City) Water Resources Department is responsible for managing the City's water, wastewater, and reclaimed water systems. The department maintains comprehensive master plans for water resources and water, wastewater, and water reuse infrastructures. The water resource master plan ensures that the City's water supplies are adequate and of good quality to meet the current and projected water demands of residents and businesses. The water, wastewater and water reuse infrastructure master plans provide for orderly growth and expansion of the infrastructure to accommodate planned City growth. The City last updated its water resource master plan in 2002 and its water infrastructure master plan in 2005. Because there have been many changes in development and land use planning since, the City commissioned the Water Resource Master Plan project which includes updates to both the Water Resource Master Plan and the Water Infrastructure Master Plan.

This Executive Summary describes the Water Resource Master Plan update. The purpose of the Water Resource Master Plan update is to incorporate changes in land use and development planning since 2002 and 2005, and to recommend how best to utilize the

City's water resources to provide an adequate and cost-effective water supply of good quality for current and future citizens.

The study area for the Water Resource Master Plan project is the City's Municipal Planning Area (MPA) north of the Estrella Mountains. The City's MPA south of the Estrella Mountains is not included in the study area because planning for this area is in the very early stages and is not yet at a level to sufficiently support detailed master planning. The City is projected to grow from a current (2009) population of approximately 70,000 to a little over 123,000 by 2030 within the study area shown on Figure ES-1. Figure ES-1 also shows Salt River Project (SRP) member lands (On-Project) which are entitled to SRP water. SRP entitlements can only be used On-Project and only up to the actual water demands within member lands.

New Planning Tools

Three useful planning tools were developed as part of the Water Resource Master Plan update. The first is a geographical information system (GIS) tool that will allow the City to evaluate any land use development scenario it wishes in developing water demand projections. The demand projection tool uses the City' most current land use planning documents, including the land use elements of the 2002 General Plan, the 2008 Avondale City Center Specific Plan, and the 2009 Draft Estrella Foothills Specific Plan. The updated land use map used for water demand projections is shown on Figure ES-2.

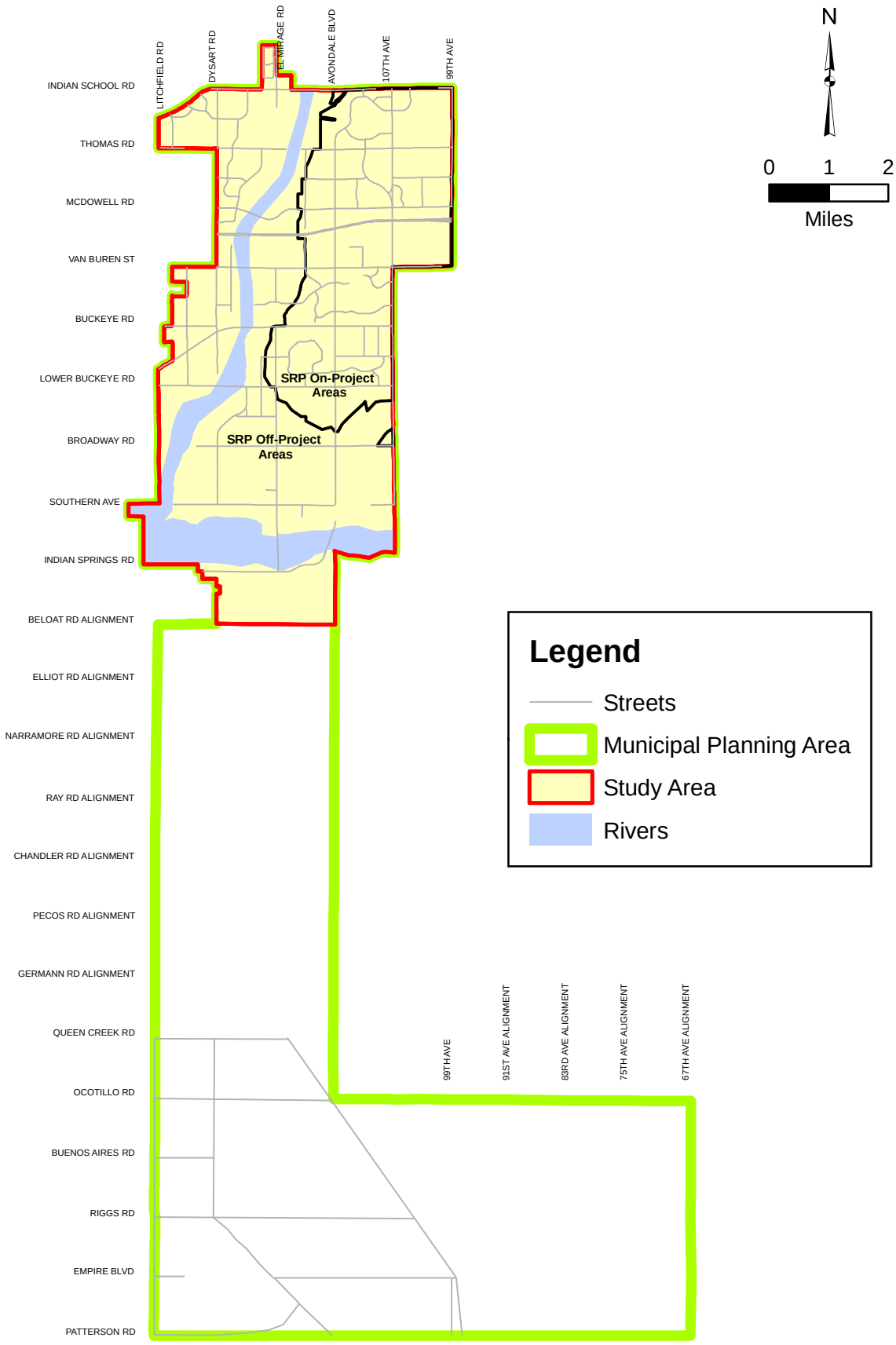
The second tool is an update to the City's water system hydraulic model that will allow the City to quickly and easily assess future water system infrastructure for the development scenarios. The third tool is a groundwater model that will allow the City to determine the long-term impacts of alternative well locations and pumping operations on local groundwater levels and movement.

Findings and Conclusions

The following significant findings and conclusions result from the information collected and analyzed and the evaluations conducted in this Water Resource Master Plan update:

Water Demands

The City's projected water demands are summarized on Table ES-1, including projections from 2010 through build-out within the study area, and a cursory analysis of build-out water demands for the City's MPA south of the Estrella Mountains.



M:\0864025\GIS\MXDs\WRMP Final Report\Figure ES-1 Study Area and On- and Off- Project Areas.mxd

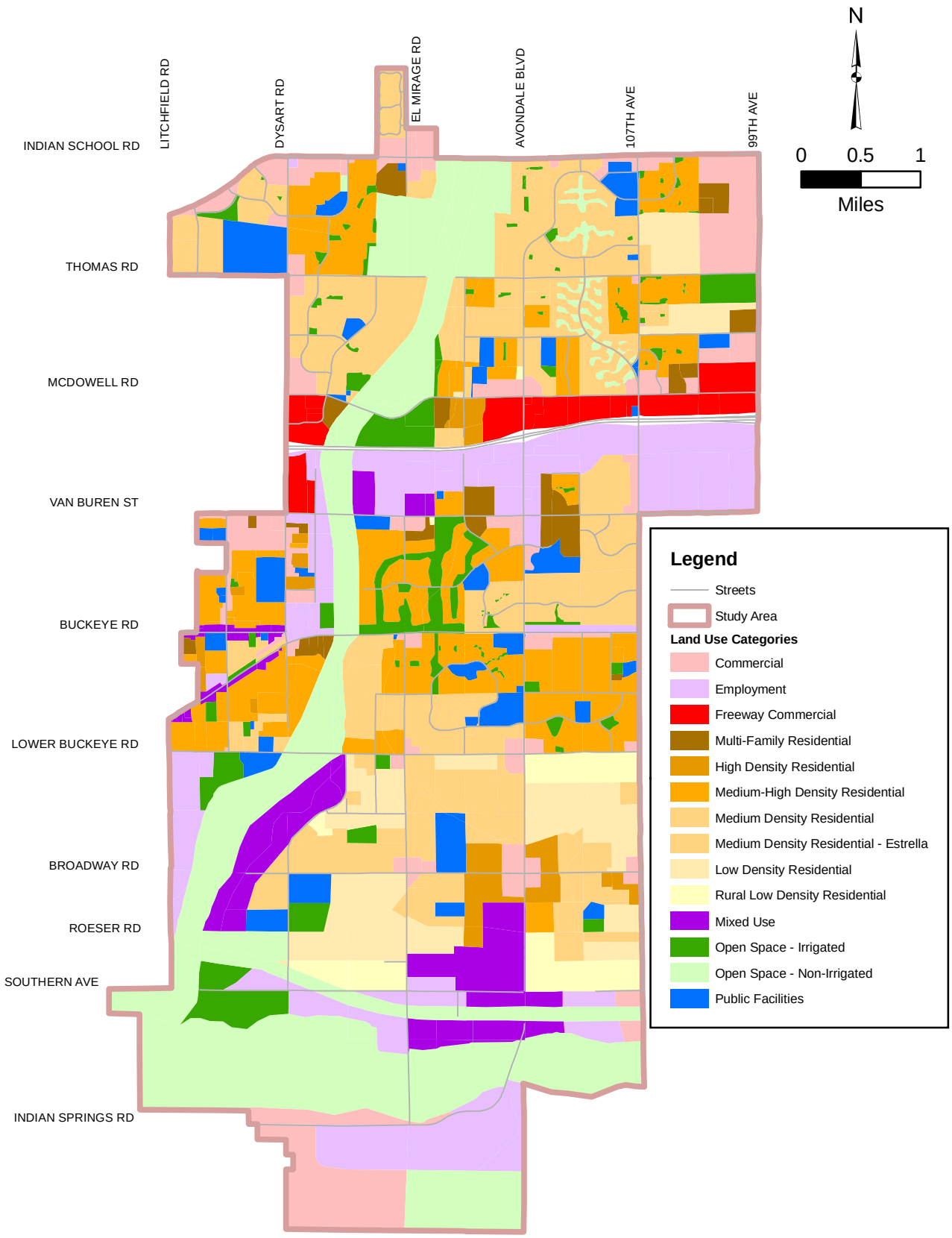
CITY OF AVONDALE, ARIZONA
WATER RESOURCE MASTER PLAN

Study Area and On- and Off- Project Areas

MALCOLM PIRNIE

May 2010

FIGURE ES-1



M:\0864025\GIS\MXDs\WRMP Final Report\Figure ES-2 Land Use Map for City Study Area.mxd

CITY OF AVONDALE, ARIZONA
WATER RESOURCE MASTER PLAN

Land Use Map for City Study Area

MALCOLM PIRNIE

May 2010

FIGURE ES-2

Table ES-1:
Baseline Water Demand Projections

	2010 (AF)	2015 (AF)	2020 (AF)	2030 (AF)	Build-out (AF)
Total Study Area	14,464	17,245	21,449	28,381	29,572
SRP On-Project	7,265	8,660	11,042	12,879	12,892
SRP Off-Project	7,199	8,585	10,407	15,502	16,681
MPA South of Estrella Mountains	--	--	--	--	7,802

Existing Water Supplies

- The City's existing Designation of Assured Water Supply (AWS) includes a total supply of 28,090 AFY from SRP entitlement and Central Arizona Project (CAP) subcontract waters and groundwater through groundwater allowances, incidental recharge, and membership in the Central Arizona Groundwater Replenishment District (CAGRD).
- On October 10, 2008, the City complied with requirements to submit an Application for Modification of its Designation of Assured Water Supply. The Arizona Department of Water Resources (ADWR) has not yet made a decision on the application. The City's existing designation is considered in effect until a final determination on the application is issued by ADWR. The Application for Modification of Designation of Assured Water Supply demonstrates that sufficient renewable supplies are available to the City to accommodate future growth, as planned, without depending on excess groundwater (groundwater to be replenished by the CAGRD).

Future Water Supplies

- Long-term renewable water supplies currently available to the Phoenix Active Management Area (AMA) have essentially been fully allocated (with the possible exception of Non-Indian Agricultural CAP water). The next large blocks of water supply for the region are believed to be brackish groundwater from the southwest Valley area, the Lower Colorado River area, and/or desalinated seawater, perhaps from as far away as Mexico. The development of these additional supplies likely will be too challenging, lengthy, and expensive for a single entity to achieve on its own. Likely, a regional water agency, such as the Central Arizona Water Conservation District (CAWCD) or Bureau of Reclamation, will implement the potential new supplies with the coordination, participation, and for the benefit of communities in the region.
- The additional water supplies that the City can reasonably rely upon in the future include additional SRP entitlements (as currently undeveloped, mostly agricultural lands get cut over to the City), reclaimed water generated within the study area, and the anticipated lease water pursuant to the White Mountain Apache Tribe (WMAT) water settlement. These additional supplies will supplement the City's existing

renewable water supplies, groundwater allowances, incidental recharge, and long-term storage credits.

Water Demand and Supply Balance

The City's projected water demand and supply balance is illustrated on Figure ES-3 and leads to the following conclusions:

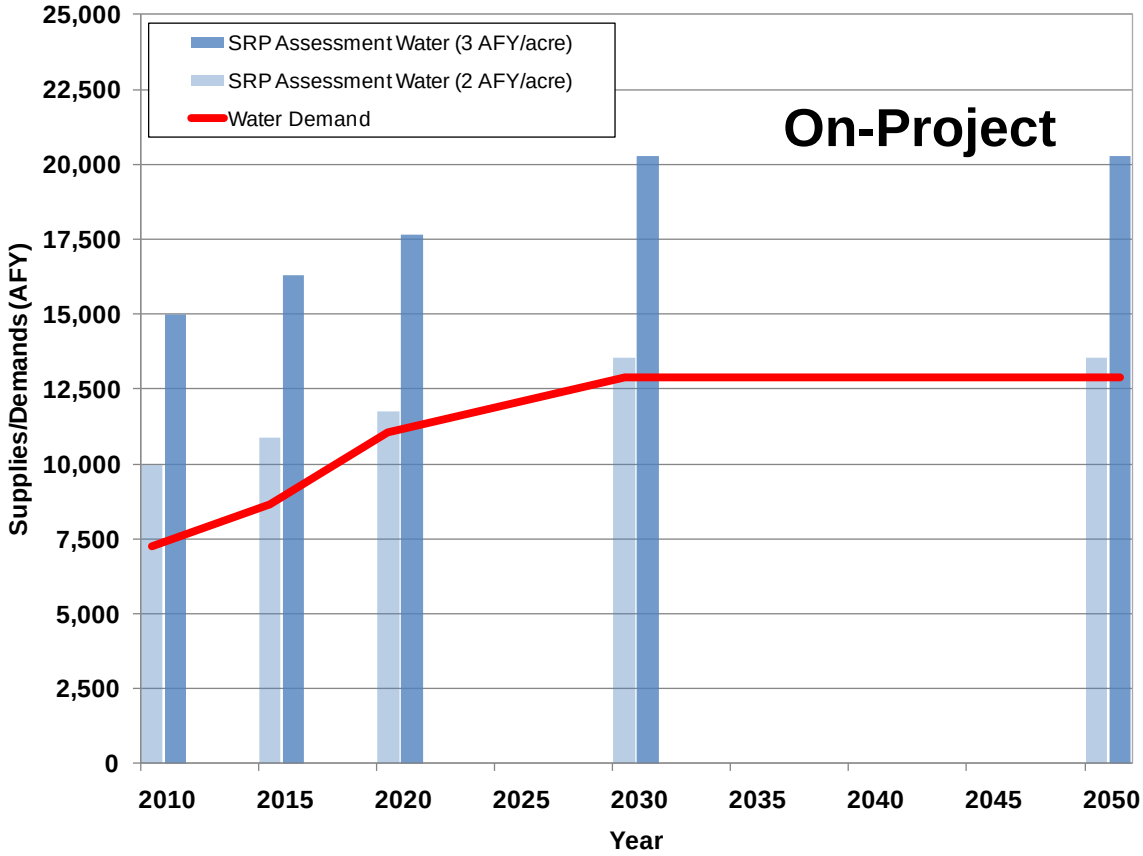
- The City's available SRP water entitlements are sufficient to support planned land uses within On-Project Areas through build-out.
- The City's remaining water supplies (CAP, long-term storage credits, groundwater allowances, reclaimed water, and the anticipated WMAT lease water) are sufficient to support planned land uses within Off-Project Areas through build-out.
- The City's available water supplies are sufficient to support planned land uses under water shortage conditions represented by SRP entitlements being cut from the normal 3 AFY/acre to 2 AFY/acre, and a 30 percent reduction in CAP water. Given the history of SRP's robust system in supplying adequate water to its member lands and the State's achievements in firming water for the Phoenix AMA, the probability of the occurrence of these water shortage conditions are generally considered low.
- The City's available water supplies are projected to be sufficient to support planned future growth without utilizing CAGRD replenishment water.

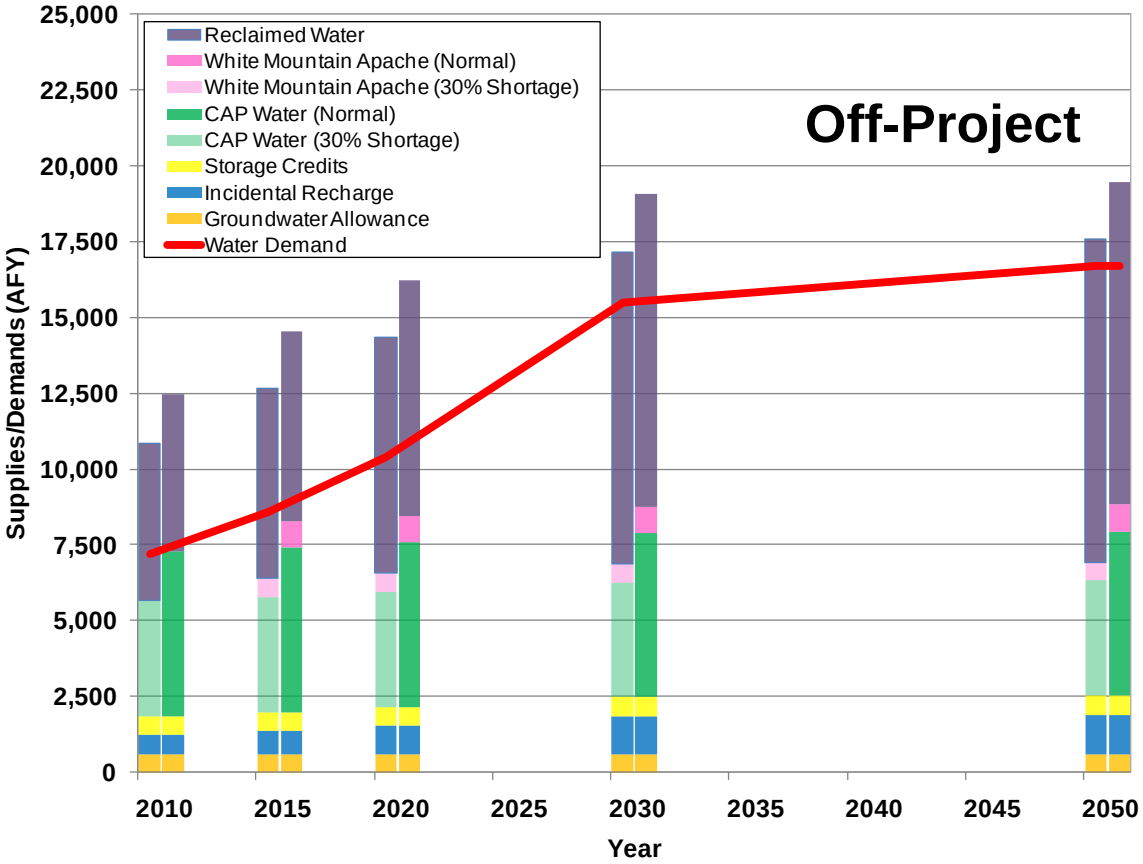
Drought/Extreme Water Shortage

- Although extreme water shortages are considered low probability, it is prudent for the City to identify a reserve of water that should be set aside for extreme drought or prolonged water supply shortages.
- Although the occurrence of reductions in water entitlements on both the SRP and CAP systems has been non-existent or minimal in recent history, a 2005 Tree Ring Study found that there is a greater than 10 percent chance that extreme shortages in both the SRP and CAP systems simultaneously could occur in any single year.
- A conservative analysis of varying levels of reductions in SRP entitlements and CAP allocations occurring simultaneously indicates that, under the worse case, the City should be prepared to withdraw up to 9,800 AF of stored water from its long-term storage account in an extreme drought year at build-out demands. Thus, conservatively, the City should store, and maintain in storage, enough water to cover up to ten extreme shortage conditions over a 100 year period (10 percent probability), or a total of 98,000 AF of long-term storage credits.

Water Supply Alternatives

- The City's alternatives for future water production and supply include 1) continuing to build wells that will recover recharged SRP, CAP, and reclaimed water, and 2) building a new surface water treatment plant (WTP) to treat the City's SRP and CAP water entitlements for direct distribution (instead of recharge and recovery).





CITY OF AVONDALE, ARIZONA
WATER RESOURCE MASTER PLAN

Baseline Scenario Demand/Supply Comparison

May 2010

Figure ES-3

- The estimated 20-year life cycle costs for the Continue to Build Wells alternatives are 20 percent less than the Build a Surface WTP alternatives. This conclusion assumes that future wells can be located and constructed to minimize or avoid groundwater treatment.
- The water supply alternative costs are sensitive to the need for future groundwater treatment for arsenic, nitrates, total dissolved solids (TDS), and other constituents that are known to be present in the City's groundwater supplies. When a reasonable upper level of additional groundwater treatment is considered, the life cycle costs for the Continue to Build Wells alternatives are 10 percent less than the Build a Surface WTP alternatives.
- Groundwater modeling of the water supply alternatives indicates that the impacts of the City's future groundwater pumping will be relatively minor, amounting to less than 17 feet of additional water level drawdown over 50 years and minimal changes in groundwater flow directions.
- A weighting and ranking of decision factors important to selecting a future water supply strategy (life cycle costs, annual operation and maintenance costs, financial [bonding] capacity, source water reliability, water quality management, system operational requirements, institutional/legal constraints, carbon footprint, and public perception) is shown on Figure ES-4, and indicates that the Continue to Build Wells alternatives are preferred over the Build a Surface WTP alternatives.

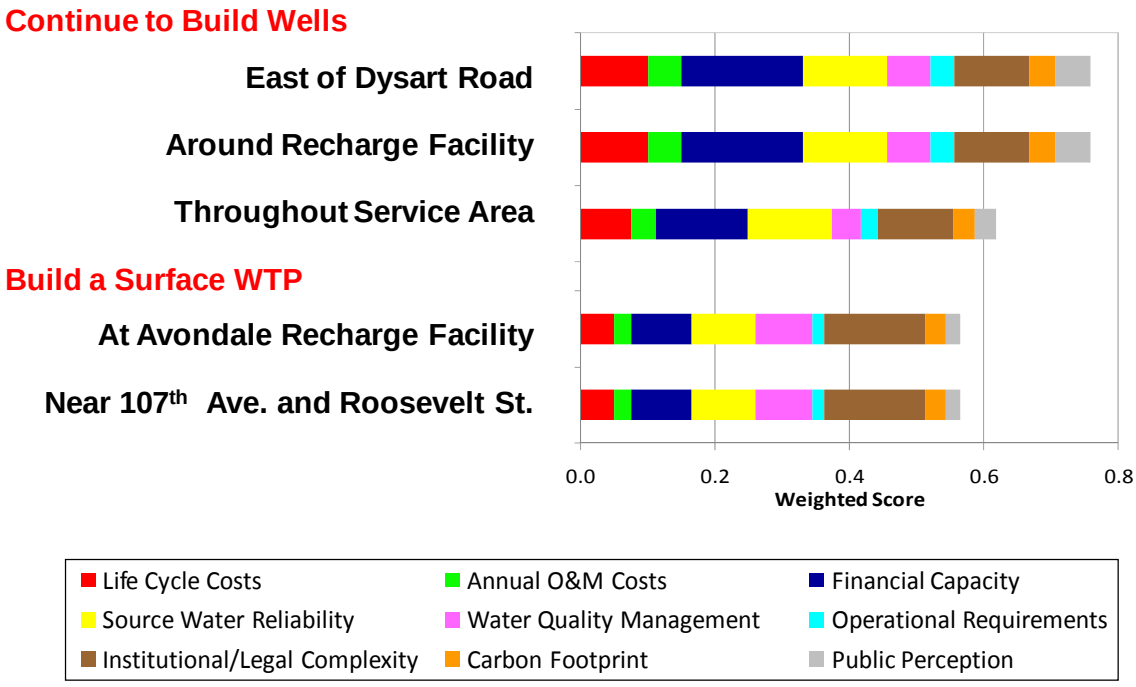


Figure ES-4: Ranking of Water Supply Alternatives

Recommendations

The work conducted in the Water Resource Master Plan update identified strategies that will allow the City to provide adequate water supplies for future growth and maintain its assured water supply status.

Recommended Future Water Supply Strategy

- The City's future water supply strategy should be to continue to build wells. This strategy will be less costly than building a new surface WTP and will be easier to fund as construction of wells can be spread out over the study period and completed as demand increases dictate.
- However, because a surface WTP may provide benefits in achieving future assured water supply designations and could alleviate the need to build additional recharge capacity, and given the inherent uncertainty for future groundwater treatment, the City should lock up a site now for a potential surface WTP. This will preserve the City's future options should a treatment plant option become necessary due to regulatory, institutional, or water quality needs.

Ongoing City Activities

The City initiated several water resources planning activities prior to the Water Resource Master Plan update project and made a commitment to continuing these activities. The work conducted in the master plan update supports the City's commitment to continue the following ongoing activities:

- Investigating alternatives for obtaining additional recharge capacity. The investigations should include 1) determining the feasibility of re-rating the Avondale Recharge Facility to a higher capacity, 2) identifying additional recharge sites within the City's service area, and 3) potentially acquiring ownership of capacity at CAWCD recharge facilities or other recharge facilities through direct purchase and/or through exchange mechanisms. The City will start to exceed the combined capacities of the Avondale Recharge Facility and the NAUSP by 2030 for recharging reclaimed water and SRP water, sooner if the NAUSP does not achieve its design capacity (which is currently questionable). In addition, long-term use of recharge capacity at CAWCD facilities for recharging CAP (and WMAT lease) water is not guaranteed.
- Periodically reviewing developer compliance with the policy of extinguishing Irrigation Grandfathered Groundwater Rights or Type 1 Non-Irrigation Grandfathered Groundwater Rights and pledging them to the City's Assured Water Supply Account, in order to increase the amount of groundwater "credited" to the City's Groundwater Allowance account maintained by ADWR.
- Building and setting aside a reserve of long-term storage credits sufficient for prolonged drought or shortages in SRP and CAP allocations. A reserve of 98,000 AF of stored water could offset groundwater pumping at build-out water demands if extreme annual droughts occurred on the SRP and CAP systems simultaneously 10

times over the next 100 years. The City's current long-term storage account balance is 43,626 AF, nearly half of the recommended target.

- Working with the City of Peoria to allow them to use Avondale's unused capacity in the NAUSP to recharge a portion of their reclaimed water in exchange for effluent credits. This arrangement will support the City's objective to acquire additional long-term storage credits for use during water emergencies and/or drought periods.
- As funding permits, acquiring and recharging excess CAP supplies to add to the City's long-term storage account.
- Federal legislation needed to settle the water rights claims of the White Mountain Apache Tribe is still under discussion by Congress at this time. The City will continue participating in the process as needed to secure ratification of the settlement as well as obtain a lease to a portion of the Tribe's CAP water entitlement provided by the settlement.
- Tracking the potential new ADWR policies related to future AWS Designations and the issues of physically available water within water providers' service areas versus underground storage of water outside of or remote from service areas. The City will continue to be a significantly involved stakeholder to preserve its best chances for future Designations of AWS.
- Taking steps to fully define the physically available water storage capability within the City's service area for future reclaimed water and CAP water to prepare for future AWS Designations. If there is inadequate storage capacity within the service area, the City should petition ADWR to determine that the water that *is* physically available within its service area is groundwater and stored water legally entitled to the City, and not to any other groundwater users or water stored by other users.
- Participating in the ADD Water and Access to Excess working groups as long as needed to determine future water supply impacts and to position the City for potential City shares in future water supplies.
- Permitting all new production wells as recovery wells so that all stored water can continue to be extracted and accounted for as non-groundwater supplies.
- Working with the City's environmental task force to evaluate conservation strategies that will be effective and widely supported. Cost-benefit analyses of promising additional strategies will be used to develop new recommendations. The strategies will be tied to overall water resources management and formalized into the City's draft Water Conservation Plan which it is currently preparing.

Other Recommendations

- The City should submit a letter of interest to CAWCD in acquiring any unallocated Non-Indian Agricultural CAP water. This is the only potentially available additional future water supply in any significant amount. This is water that has been "released" from those who initially had received an allocation of this water for any number of reasons, and is not currently allocated to any specific CAP subcontractor. While this water may be in excess of current water demand projections for the City, it may still

be useful in helping to build and maintain the City's reserve drought supply, or become a supply for water demands that may occur in excess of those contemplated herein (e.g., the City's MPA south of the Estrella Mountains).

- If the City wishes to be considered for any future CAP M&I supplies that become available for any reason, it should also submit a letter of interest to ADWR and CAWCD expressing a desire to acquire any CAP M&I subcontracts that may be offered for sale. While the chances for success are unknown, the City should at least have its interest in additional CAP water on record.
- After the City receives approval of its current Application for Modification of Designation of Assured Water Supply, and as availability of renewal water supplies is strengthened (SRP, CAP, reclaimed, WMAT lease, etc.), the City should reassess its continued membership in CAGRD.
- The City should continue to geo-locate all water meters. This will enhance the review of water demand patterns and development of water demand factors in the next update of the Water Resource Master Plan.

THIS PAGE INTENTIONALLY LEFT BLANK

1. Introduction

1.1. Background

The City of Avondale (City) Water Resources Department is responsible for management of the City's water, wastewater, and reclaimed water systems. The department maintains comprehensive master plans for water resources and water, wastewater, and water reuse infrastructures. The water resource master plan ensures that the City's water supplies are adequate and of good quality to meet the current and projected water demands of residents and businesses. The water, wastewater, and water reuse infrastructure master plans provide for orderly growth and expansion of the infrastructure to accommodate planned City growth. The City last updated its water resource master plan in 2002 and its water infrastructure master plan in 2005. Because there have been many changes in development and land use planning within the City since 2002 and 2005, the master plans are in need of updating.

In July 2009, the City retained Malcolm Pirnie, Inc., in association with Replenishment Services, LLC, to complete the Water Resource Master Plan project which includes updates to both the Water Resource Master Plan and the Water Infrastructure Master Plan. This report contains the Water Resource Master Plan.

1.2. Project Purpose and Scope

The purpose of the Water Resource Master Plan update is to incorporate changes in land use and development planning and capital improvement program achievements since 2002 and 2005, and to recommend how best to utilize the City's water resources to provide an adequate and cost-effective water supply of good quality for current and future citizens. The scope of the Water Resource Master Plan update generally includes the following:

- Development of water demand projections
- Assessment of existing and potential future water supplies to meet demands
- Evaluation of alternatives for supplying water including continuing to build wells and potentially building a water treatment plant
- Selection of a preferred water supply alternative
- Development of recommendations to maintain the City's assured water supply designation and an adequate, secure, reliable water supply in the future

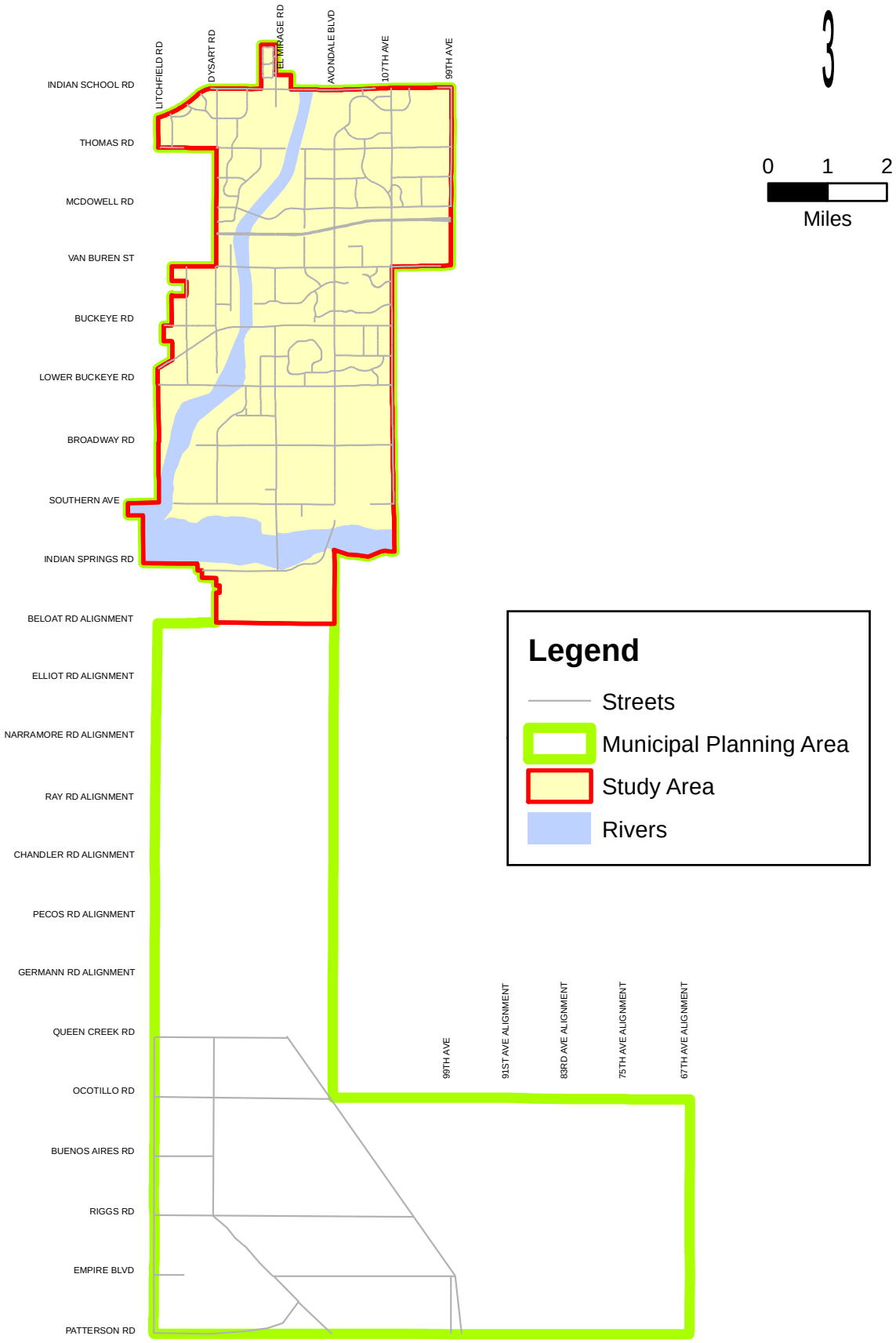
Water demands were forecasted using a geographic information system (GIS)-based tool, developed for this project. The tool easily and quickly compares projected water demands against available water supplies for any development scenario that the City could envision (changes in land uses, residential densities, growth rates, etc.). The project also included a hydrogeologic study and development of a groundwater model to assess the impacts to groundwater levels and movement due to long-term groundwater pumping.

1.3. Study Area

The study area for the Water Resource Master Plan project is the City's Municipal Planning Area (MPA) north of the Estrella Mountains. The City's MPA and project study area are illustrated on Figure 1-1. The City's MPA south of the Estrella Mountains is not included in the study area because planning for this area is in the very early stages and is not yet at a level to sufficiently support detailed master planning. However, the City requested a cursory analysis of potential build-out water demands within its MPA, including south of the Estrella Mountains. According to the City Finance Department, the City is projected to grow from a current population of approximately 70,000 to a little over 123,200 by 2030 within the study area (Appendix A).

Within the study area, water demand projections are presented for the following areas:

- **Salt River Project (SRP) On-Project and Off-Project Areas.** On-Project Areas are lands that are within the service area of SRP, while Off-Project Areas are outside the SRP service area. Figure 1-2 illustrates the SRP On- and Off-Project Areas.
- **Service Area Lands and Future Service Area Lands.** Service Area Lands are those lands within the study area that currently receive water service from the City. Future Service Area Lands are those lands within the study area that do not yet receive City water service and include agricultural lands, vacant land, and land served by other water providers. The City will extend service to Future Service Area Lands as they develop. Figure 1-3 illustrates the Service Area and Future Service Area Lands.



\\phoenix\projects\0864025\GIS\MXDs\WRMP Final Report\Figure 1-1 Municipal Planning Area and Study Area.mxd

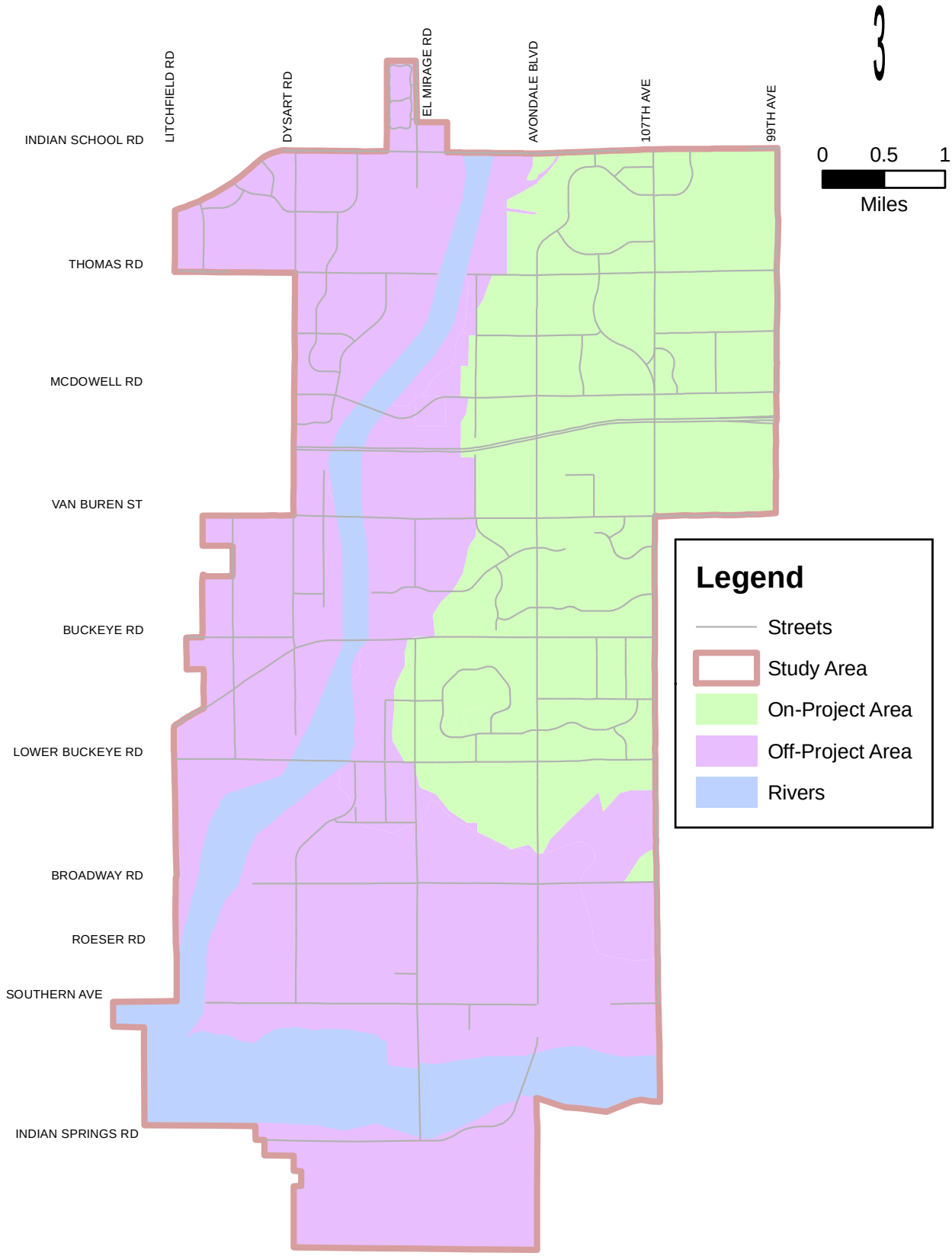
CITY OF AVONDALE, ARIZONA
WATER RESOURCE MASTER PLAN

Municipal Planning Area and Study Area

MALCOLM PIRNIE

May 2010

FIGURE 1-1



M:\0864025\GIS\MXDs\WRMP Final Report\Figure 1-2 SRP On-Project and Off-Project Areas.mxd

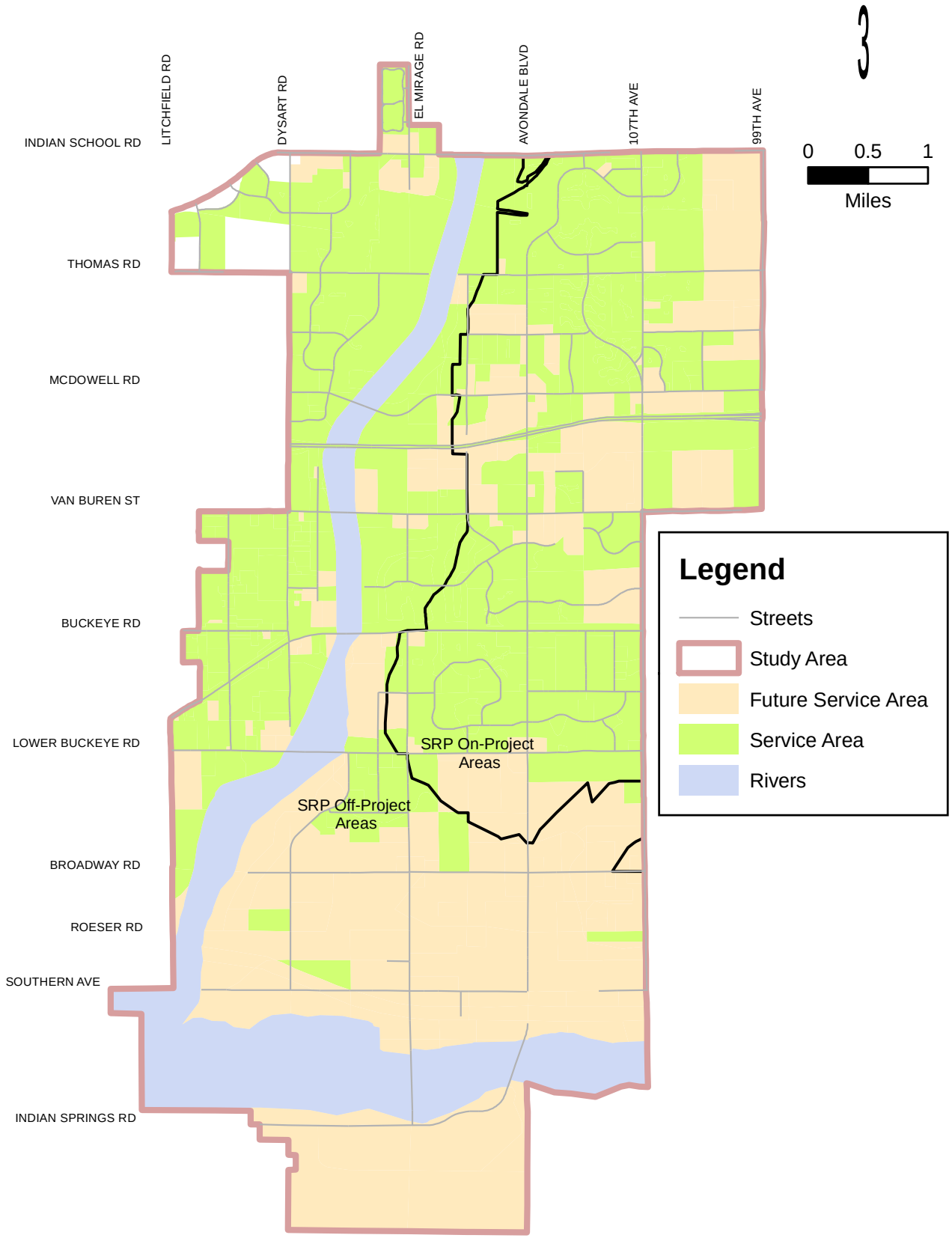
CITY OF AVONDALE, ARIZONA
WATER RESOURCE MASTER PLAN

SRP On-Project and Off-Project Areas

MALCOLM PIRNIE

May 2010

FIGURE 1-2



M:\0864025\GIS\MXDs\WRMP Final Report\Figure 1-3 Service Area and Future Service Area Lands.mxd

CITY OF AVONDALE, ARIZONA
WATER RESOURCE MASTER PLAN

Service Area and Future Service Area Lands

MALCOLM PIRNIE

May 2010

FIGURE 1-3

THIS PAGE INTENTIONALLY LEFT BLANK

2. Regulatory and Institutional Framework

There are many laws, contracts, policies, and ordinances on Federal, State, and City levels that govern the use of water resources. This section summarizes the key components of several regulations and institutional constraints that are important to water resources planning in the City. The summaries presented are interpretations of the regulations and do not substitute for official regulatory language; references to sections in the Arizona Revised Statutes, Arizona Administrative Code, and Federal Register are provided for further reading.

2.1. Groundwater Management Act

The Groundwater Management Act was enacted in 1980 to manage groundwater resources in Arizona. The Act created four initial Active Management Areas (AMA) (Phoenix, Pinal, Tucson, and Prescott; Santa Cruz was added later) in areas with severe groundwater overdraft and existing and projected urban growth. The primary management goal of the Phoenix AMA (where the City of Avondale resides) is to reach a level of safe yield of the groundwater resources by 2025. The act has been codified (Groundwater Management Code) in the Arizona Revised Statutes (A.R.S.) Title 45 – *Water* and governs the allocation and use of water resources in Arizona. Title 45 is subdivided into 16 chapters; each chapter is subdivided again into articles, which contain the specific statutes. The Groundwater Management Code is a very detailed and comprehensive law; this section focuses on the portions of the code most relevant to the City's water resources planning efforts, including the following key provisions:

- **Chapter 2, Article 6** relates to "Groundwater Rights and Uses within Service Areas" and regulates the withdrawals of groundwater by cities, towns, and private water companies within their service areas. This article provides authority to cities to withdraw and transport groundwater within their service areas for the benefit of their landowners and residents. The article also contains specific provisions against expansions of service areas specifically to include a well field or to withdraw and distribute groundwater for irrigation purposes (agricultural). Along with a few other related provisions, the article also requires cities to retain updated maps of their water service areas.
- **Chapter 2, Article 7** relates to groundwater withdrawal permits. These are permits that have a limited term and are typically used for special purposes, such as a hydrologic testing permit for well drilling. Groundwater rights are typically not time restricted, whereas permits have an expiration date**.**

  Chapter 2, Article 9 addresses the management of groundwater supplies. This article allows the Arizona Department of Water Resources (ADWR) to develop

management plans for the AMAs. This article authorizes the specific conservation program options to operate within specific provisions that relate to Assured Water Supply Certificates and Designations, adoption of administrative rules needed to carry out the provisions of the statutes, the requirements for planning by the Central Arizona Groundwater Replenishment District (CAGRD), and water conservation and water district plans. ADWR must adopt a series of management plans for each AMA designed to achieve the AMA's management goal. For the time period of 2000 through 2010, the Third Management Plan in the series of five plans is in effect. The management goal for the Phoenix AMA is safe-yield (A.R.S. § 45-562). Safe-yield is a long-term balance between the annual amount of groundwater withdrawn in the AMA and the annual amount of natural and artificial recharge in the AMA (A.R.S. § 45-561). Each management plan must include a continuing mandatory conservation program for all persons withdrawing groundwater in the AMA (A.R.S. § 45-563).

- **Chapter 2, Article 10** relates to wells and will be further discussed in Section 2.9 of this chapter.
- **Chapter 2, Article 11** relates to the financial provisions of the ADWR and what fees the ADWR may charge in its role administering the provisions of the Groundwater Management Code.
- **Chapter 2, Article 12** relates to the enforcement authority of the ADWR.
- **Chapter 2, Article 15** relates to obtaining a Certificate of Groundwater Oversupply.
- **Chapter 3.1** addresses Underground Water Storage, Savings, and Replenishment.
- **Chapter 4** addresses water exchanges.

The remaining chapters of Title 45 may, from time to time, affect various uses and management of water resources, but they are very specific as to their application and tangential to the water resources planning and management functions.

2.1.1. Assured Water Supply Designation

When the Groundwater Management Code was being developed, the Groundwater Management Study Commission recommended that the State of Arizona prohibit urban development in areas where no assured water supply (100 years of supply) is available. The Groundwater Management Code includes this recommendation. In an AMA, a person proposing to sell subdivided or un-subdivided land must obtain a Certificate of Assured Water Supply (AWS) from the Director of ADWR prior to any sale. Alternatively, the Director of ADWR designates service areas of cities, towns, and private water companies where assured water supplies exist. As a result, developers within designated service areas are not required to obtain their own certificates of assured water supply.

The Director of ADWR has adopted rules to implement the assured water supply provisions. These rules are located under Title 12, Natural Resources, Number 15, ADWR, Article 7, Assured and Adequate Water Supply (A.A.C. R12-15-701 through

R12-15-730). Under the rules, groundwater in the Phoenix AMA is "physically available" only if it is pumped from a depth that does not exceed 1,000 feet below land surface (A.A.C. R12-15-716.B.2). Central Arizona Project (CAP) water is physically available if the provider has a long-term subcontract for CAP water. Other CAP water is defined as physically available only if the provider demonstrates a back-up supply of water. Surface water other than CAP water (such as water from the Salt River Project) is defined as physically available under a formula provided in the rules.

If a proposed source of water for an assured water supply is water to be recovered from an underground storage project, the volume of water legally available is represented by stored water credits existing on the date of the application for designation of an assured water supply. If the applicant wants to use credits for stored water that do not exist at the date of the application, ADWR will consider the physical availability of the water to be stored and the presence of an existing storage project in determining whether to include the proposed credits.

The AWS Rules limit the amount of groundwater a municipal provider may withdraw "consistent with the management goal" of the AMA. The volume of groundwater the provider may withdraw is calculated pursuant to rule A.A.C. R12-15-722.A and B. The amount of groundwater use allowed can be increased through several mechanisms. The first increase to the allowable groundwater use is by an incidental recharge baseline factor of, typically, 4 percent of water use. The amount of groundwater use allowed may also be increased by the amount of credits obtained for the extinguishment of irrigation grandfathered water rights (known as extinguishment or assured water supply credits).

The Groundwater Management Code provides a mechanism for a designated provider to increase the amount of groundwater it may withdraw pursuant to the assured water supply rules. Under A.R.S. § 45-576.01, ADWR may find that a water provider's additional use of groundwater is consistent with the management goal if the provider is a member service area of the CAGRD and ADWR has approved CAGRD's plan of operation. As long as the groundwater is physically available, the municipal provider may pump more groundwater than the assured water supply rules allow. However, as a member of CAGRD, the provider must pay a fee to CAGRD for recharging a like amount of water. CAGRD is discussed in more detail in Section 2.2 of this chapter.

According to Administrative Rule R12-15-724.A.4, for each calendar year of a designation, the Director of ADWR shall calculate the volume of incidental recharge by multiplying the provider's total water use from any source in the previous calendar year by the standard incidental recharge factor of 4 percent. This water is added to the groundwater allowance account and can be used to reduce the City's CAGRD replenishment obligation.

All Grandfathered Groundwater Rights (Type 1, Type 2, and Irrigation) are eligible for extinguishment, and the resulting credits can be pledged and added to a designated provider's allowable groundwater account. These credits can be used in the designation of assured water supply, but they only represent 1 acre-foot (AF) per credit for the entire 100-year designation. However, these credits can be used to reduce the obligation to the CAGRD, similar to incidental recharge and groundwater allowance credits.

Currently, the rules state that the Director of ADWR shall review a designation at least every 15 years following issuance of the designation to determine whether the water provider's designation should be modified or revoked (A.A.C. R12-15-715.C). After notification and initiating a review, the Director of ADWR may revoke the designation for any of the following reasons:

- The provider has less water than the amount required for a 100-year supply for the provider's current demand, committed demand, and projected demand for the next two calendar years.
- The provider fails to construct adequate delivery, storage, and treatment works in a timely manner.
- Arizona Department of Environmental Quality (ADEQ) or another governmental entity with equivalent jurisdiction has determined, after notice and an opportunity for a hearing, that the designated provider is in significant noncompliance with A.A.C. 18, Chapter 4 and is not taking action to resolve the noncompliance.

According to the ADWR, all designated water providers in the Phoenix AMA were required to apply for a modification of Designation of Assured Water Supply by 2010. ADWR required that the same procedures, models, and assumptions be used by all applicants to ensure that the approach to physically available groundwater is consistent for all water providers. *Avondale submitted an application for Modification of Designation of Assured Water Supply in October 2008.*

2.1.2. Groundwater Rights

The Groundwater Management Code created several different classes of groundwater rights within AMAs. With the exception of service area rights, no additional groundwater rights can be created within AMAs. There are provisions for other types of temporary groundwater withdrawals under permit systems.

Groundwater Rights for water users were established during a 5-year period (1975 to 1980) of qualification that preceded the passage of the Groundwater Management Code. During this period, groundwater must have been used or a substantial capital investment needed to have been made with the intent of using groundwater. These uses were "grandfathered", hence the term "grandfathered groundwater rights."

Other than service area rights, which are discussed below, there are three basic classes of groundwater rights:

- The use of groundwater for commercial agriculture resulted in the establishment of Irrigation Grandfathered Groundwater Rights. These rights are appurtenant, or attached, to the land where the rights were established. With very few exceptions (e.g., substitution of lands damaged by floods), these rights cannot be moved from the land where they were established. If the land is to be converted to some other type of non-irrigation use (e.g., a dairy, golf course, residential subdivision, or industry) and the land is not located within a specified distance of an existing potable water provider, the irrigation right can be converted to a Type 1 non-irrigation right. This process is referred to as "retirement" because the irrigation use is retired to a non-irrigation use. This process is irreversible, meaning that once an irrigation right has been converted to a Type 1 non-irrigation right, it cannot be changed back for use on irrigated agriculture.
- If groundwater was used for a non-irrigation use during 1975 to 1980, a Type 2 Grandfathered Groundwater Right was issued. This right is unique in that it can be leased or sold to other water users anywhere within the AMA. With respect to a lease, the entire right or only a portion of it may be leased.

Based on review of ADWR's online database, the City of Avondale appears to have two certificated Irrigation Grandfathered Groundwater Rights, one certificated Type 1 Non-Irrigation Grandfathered Groundwater Right in the amount of 6.96 acre-feet per year (AFY), and one certificated Type 2 Non-Irrigation Grandfathered Groundwater Right in the amount of 68 AFY. The City is in the process of extinguishing the Type 1 right and plans to retain the Type 2 right for possible future use.

2.1.3. Service Area Rights

Service area rights are also unique in that they have the ability to be expanded, and they are the only groundwater right that can still be created within an AMA. There are specific methods for expanding/extending existing service area rights and for establishing new or "satellite" service areas. *The City operates its potable water delivery system under the authority of a service area right.*

2.1.4. Third Management Plan

To achieve the management goal for each AMA, water management requirements are established in each of the five management periods. The Third Management Plan addresses the ADWR's long term water management strategy, with particular emphasis on the third management period (2000 to 2010).

The Third Management Plan is organized into 12 chapters that address water supply, demands, and management issues for the Phoenix AMA for all sectors of water use. It includes water conservation requirements for agricultural, municipal, and industrial groundwater uses; a water quality assessment and management program; an

augmentation and recharge program; conservation and assistance programs; and other management programs.

The third management period constitutes the midpoint in Arizona's effort to achieve its groundwater management goals. After the end of the third management period in 2010, there will only be 15 years left to achieve safe yield by 2025. The Third Management Plan identifies a water management strategy that encompasses the use of water conservation, augmentation, recharge, and water quality management by the agricultural, municipal, and industrial sectors to achieve the water management strategy during the third management period. All water users must continue to commit to using available water supplies efficiently and to making additional use of renewable supplies to replace existing groundwater use and to meet growing water demands.

The Third Management Plan was modified in May of 2003. The modifications focused on the water conservation programs and ADWR's Water Management Assistance Program. In 2007, legislation was enacted requiring the Third Management Plan to include a Modified Non-Per Capita Water Conservation Program (Modified NPCCP). This program requires that large municipal water providers that are not designated as having an assured water supply (and are not a large untreated water provider, e.g., SRP) be regulated under the Modified NPCCP beginning January 1, 2010. There are some specific exceptions based upon approvals by the ADWR. The Modified NPCCP is optional for designated water providers *Since the City is designated, it is not impacted by this requirement, but it may choose to consider this option in the future.*

Most of the requirements of the management plan are focused on water conservation. The primary goal of the municipal conservation program is to assist in moving the AMA toward safe yield by reducing per capita water consumptions, encouraging the use of the best available water conservation practices, and maximizing the efficient use of all water supplies including, for instance, effluent (reclaimed water) directly used or stored underground and recovered within the area of impact.

2.1.5. Fourth Management Plan

ADWR is currently preparing to draft the management plan for the fourth management period. Currently, ADWR staff is evaluating progress towards the management goal (safe yield) for the Phoenix AMA. At the conclusion of this process, efforts in drafting the actual plan are scheduled to begin. General guidelines for the Fourth Management Plan are found in A.R.S.45 §45-567. The guidelines for the Fourth Management Period are similar to those for the Third Management Plan. *The plan may include additional water conservation requirements for the City of Avondale*.

2.2. Central Arizona Groundwater Replenishment District

In 1993, the State legislature created a groundwater replenishment authority to be operated by the Central Arizona Water Conservation District (CAWCD) throughout Maricopa, Pinal and Pima counties. This replenishment authority, the CAGRD, is a division of CAWCD. In 1999, the legislature expanded CAWCD's replenishment authorities and responsibilities by passing the Water Sufficiency and Availability Act. The purpose of the CAGRD is to provide a mechanism for landowners and water providers to demonstrate an AWS under the new AWS Rules which became effective in 1995. The CAGRD recharges unused CAP water, or other renewable water supplies, in order to offset groundwater pumping by its members. For those entities and developers who lack access to CAP water or other renewable supplies, membership in the CAGRD provides a mechanism to meet the AWS requirements.

Membership in CAGRD may be through Member Service Areas or Member Lands. In subdivision developments served by private water companies without an AWS designation, the developer enrolls their lands in the CAGRD as a Member Land and homeowners are assessed a replenishment tax based on water use as a part of their property taxes. Designated municipal providers are enrolled in the CAGRD as a Member Service Area and are assessed a fee based on the amount of water replenished on their behalf. According to the CAWCD rate schedule adopted June 4, 2009, the current cost of using groundwater that must be replenished (excess groundwater) is $318/AF.

The CAGRD currently has approximately 23 Member Service Areas and 1,000 Member Lands, with long-term replenishment obligations of up to 225,000 AFY. In the last real estate development boom, many more lands were enrolled than anticipated within the CAGRD's 10-year plan of operation. This created an obligation for the CAGRD to obtain water supplies adequate to replenish water to offset the associated future withdrawals.

The CAGRD is required only to replenish withdrawals within the AMA, as opposed to being specifically within the vicinity of where the water was extracted. In 1999, the CAGRD rules were amended to allow limited direct delivery to areas that lack physically available groundwater. This was made possible through a Water Availability Status Membership. This type of membership commits the CAGRD to replenish a specified annual average volume in a location where the provider has physical access to service the members, provided it would have otherwise been replenished and recovered in the same year of delivery. In accordance with existing statutes, the CAGRD may grant a water availability status maximum total of 20,000 AFY of replenishment obligation. This provision was included in statute to save costs for members. *The City has not sought a Water Availability Status Membership with CAGRD, but is a Member Service Area.*

Member Service Areas are not required to pay a replenishment obligation to the CAGRD for using excess groundwater if the water is accounted for as 100 percent recovered credits derived from renewable water stored underground from permitted recovery wells; and/or, renewable water delivered through an annual storage and recovery project where water is recovered in the same year it is stored. *The City can now avoid incurring a replenishment obligation by virtue of the fact that all of the City's wells are now permitted as recovery wells.*

2.3. Underground Storage and Savings

Arizona has established a comprehensive program to encourage and regulate artificial recharge in groundwater basins (Title 45, Chapter 3.1, Underground Water Storage, Savings and Replenishment). The most common types of water used for recharge purposes are CAP and Salt River Project (SRP) supplies and reclaimed water. ADWR must permit the recharge activity if the recharging entity proposes to recover the supply for future use. Permits are required for recharge, storage, and recovery. In addition, Aquifer Protection Permits may also be required from ADEQ for recharge of non-CAP supplies (A.R.S. § 49-241).

2.3.1. Recharge

Within the context of the Arizona Revised Statutes and the ADWR administrative rules, the term "recharge" is used to describe the addition of water to the aquifer without intent to establish storage credits to recapture the water through recovery wells. The proper legal terminology used for what is typically thought of as recharge is "non-recoverable water." This is addressed under Article 3 of Chapter 3.1, A.R.S. §45-833.01.

Except as provided for in the statutes governing the replenishment of groundwater, underground storage (with the resulting storage credits then established for "recovery" purposes to prevent water from being classified as groundwater) is the more common method of operation.

2.3.2. Storage and Recovery

There are two permits involved in underground storage projects; they are the Underground Storage Facility Permit governed by Chapter 3.1, Article 2 of the A.R.S. and the Water Storage Permit governed by Chapter 3.1, Article 3 of the A.R.S. The Underground Storage Facility Permit is the permit that regulates the "how" of underground storage. There are two types of physical facilities that are permitted:

- Constructed – a constructed facility is a facility that is actually built such as spreading basins, injection wells, and vadose zone wells
- Managed – managed facilities exist where water is discharged into a natural stream and water is allowed to infiltrate through natural processes

There is a third type of facility, which is known as a groundwater savings facility. This is a water exchange and has also been called in-lieu or indirect underground storage. This typically is accomplished through the delivery of a renewable water supply (such as CAP water) to a user of groundwater (typically an irrigation district) that has access to a CAP canal but is unable to use it directly because of institutional, financial, or other ADWR deemed appropriate reasons. For groundwater savings facilities, the renewable water is delivered to the irrigation district or groundwater user who agrees to reduce groundwater pumping gallon for gallon for the water being delivered. The entity providing the renewable water gets credits to the amount of water delivered minus transportation losses and, except for reclaimed water, a 5 percent cut to the aquifer. This type of project is used to acquire credits quickly and inexpensively, and the user of the water (the irrigation district) also contributes to the cost of the water since they are saving energy by not pumping groundwater.

A water storage permit is the permit that is issued to the entity that wishes to accrue the credits. This is the permit that regulates the "how much to whom" aspect of underground storage activities. Recovery well permits are required if stored water credits are to be withdrawn from a well. An existing well can be permitted as a recovery well, subject to approval of an application to ADWR that demonstrates that other wells in the vicinity will not be harmed by the recovery of stored water from the well. Water may be recovered from any well located within the same AMA subject to the conditions issued pursuant to the permit. The water recovered from the well retains the identity of the water when it was stored. For example, if CAP water was stored, it is accounted for as recovered CAP water for the purposes of annual reporting to the ADWR. Credits can be stored for longer than one year and are therefore classified as long term storage credits. If credits are to be recovered in the same year they are stored (annual storage and recovery project), they are classified as annual storage credits.

The City has been using underground storage and recovery to manage its CAP and SRP water supplies and started using this approach with reclaimed wastewater in late 2009. The Avondale Recharge Facility is permitted as a constructed underground storage facility, and all City wells are currently permitted as recovery wells.

2.3.3. Exchanges

The Groundwater Management Code allows managing groundwater resources through water exchanges. Water exchanges involve the exchange of one water supply for another, either to avoid the costs of physically moving water or to match water supplies of varying qualities with appropriate uses.

Water exchanges are covered under A.R.S Title 45, Chapter 4. A.R.S. § 45-1001 defines a water exchange as "a trade between one or more persons, or between one or more

persons and one or more Indian communities, of any water for any other water, if each party has a right or claim to use the water it gives in trade." A.R.S. Title 45, Article 2 addresses the enrollment of water exchange contracts, which is specific to contracts and amendments that pre-date 1994 and 1995, respectively. A.R.S. Title 45, Article 3 addresses applications, fees and permits for water exchanges.

The City of Avondale and SRP operate under exchange provisions in order to balance the availability of SRP surface water with demands associated with SRP eligible lands and to optimize operation of the City's water production and distribution system.

2.4. Water Transfer Legislation

Water transfers are covered under A.R.S. Title 45, Chapter 2, Article 8, which relates to the transportation of groundwater. The key provision of this article allows for a water provider to transport groundwater within a sub-basin within its service area without payment of damages to other groundwater users. Chapter 2, Article 8.1 addresses the provision for the transportation of groundwater from the Butler Valley and Harquahala Irrigation Non-Expansion Area and the prohibition against transportation of groundwater from other areas.

2.5. Central Arizona Project Subcontract

The delivery of Colorado River water through the CAP Canal is done pursuant to a subcontract between the City, the CAWCD, and the United States Secretary of the Interior. The delivery subcontract prescribes the delivery conditions and repayment obligations. The CAWCD administers and manages the CAP under its contract with the United States Bureau of Reclamation for the State of Arizona.

2.5.1. Water Delivery Subcontracts

CAWCD's contract with the United States Bureau of Reclamation authorizes CAWCD to subcontract with individual users of CAP water and includes provisions for repaying the United States for the cost of constructing the CAP. These provisions have been amended in part by Indian water rights settlements.

For the purposes of this chapter, all CAWCD rates are those listed in the rate schedule adopted by the CAWCD board June 4, 2009. The cost associated with a CAP municipal and industrial (M&I) contract includes a CAP water capital repayment obligation. This obligation is calculated and required to be paid based upon the subcontractor's full allocation annually regardless of the amount of water delivered. The rate for 2010 is set at $15/AF. The advisory rate for 2011 (subject to change) is set at $12/AF.

Delivery charges for CAP water ordered under an M&I subcontract include the costs of operations, maintenance, and repair/replacement and energy. This rate is set each year by

the CAWCD board and is set at $118/AF for 2010. The advisory rates for 2011 through 2014 are scheduled at (per AF) $127, $136, $144, and $149, respectively.

Additional deliveries of CAP water can be requested under excess water subcontracts and incentive recharge subcontracts. The incentive recharge rate for 2010 is $133/AF, matching the cost of excess water. Incentive recharge water is scheduled to be eliminated in 2011. The advisory rates for excess water for 2011 through 2014 are scheduled at (per AF) $139, $136, $144, and $149, respectively. Excess water is currently projected to be available by the CAWCD for direct use and underground storage.

2.5.2. Direct Underground Water Storage Facility Contracts

CAWCD owns and operates a number of underground water storage facilities, including three in the Phoenix AMA. An additional project is under development in the Phoenix AMA. The three operational facilities are the Agua Fria, the Hieroglyphic Mountains, and the Tonopah Desert.

The CAWCD rates for storage of water at facilities in the Phoenix AMA (per AF) are $8 for 2010, and advisory rates for 2011 through 2014 are set at $9, $10, 11, and $11, respectively. Municipalities are not charged a capital charge for storage in CAP storage facilities.

The City has contracts to store water in two of the CAWCD storage facilities: up to 40,000 AFY at the Agua Fria facility and an additional 20,000 AFY at the Hieroglyphic Mountains facility. A key provision in each agreement requires that the City indicate the amount of water the City desires to store each year by October 1 of the preceding year. CAWCD is required to notify the City of the amount of storage available to the City by November 15 of the same year the order is placed. This is important because the agreement is not a guarantee that capacity in the facility will be available to the City on an annual basis. While not likely in the near term, it could be possible that the City could be in a position to have CAP water available but no CAWCD facility with capacity to receive and store the water. The existing agreements are for five-year terms. *The City's agreements will be renewed in 2010 and each will have 10-year terms.*

2.6. Salt River Project

2.6.1. Water Delivery and Use Agreement

The Salt River Valley Water Users Association (SRVWUA) is the agent for the SRP Agricultural Improvement and Power District, a political subdivision of the State of Arizona, in the operation of the water delivery system of the SRP. Cities that receive water from SRP, to deliver water to member lands in the potable water delivery system, do so under the provisions of an agreement with SRP. This agreement, known as a Water Delivery and Use Agreement (WDUA), specifies how water that is appurtenant, or attached, to specific lands can be used and how it must be accounted for by the receiving

city. *The City of Avondale entered into a WDUA with the SRVWUA December 17, 1996. The Agreement remains in effect through December 31, 2101.*

The WDUA authorizes contracted cities to receive water pursuant to water rights to the Salt and Verde Rivers that are and remain appurtenant to lands within the city's water service area. The cities are also authorized under the agreement to deliver some of the water it receives from the SRVWUA to lands that are not entitled to this water, but in exchange the cities will deliver other water it controls (municipal water) to the SRVWUA or directly to lands entitled to water from the SRVWUA. The cities may also connect specific SRVWUA wells to the city's water system to better enable them to serve lands with rights to water from the SRVWUA.

The WDUA specifies that the cities shall pay the assessments (SRVWUA charges) for all lands within the city's service area with rights to receive water from the SRVWUA except lands receiving water from the SRVWUA for agricultural uses or directly from the SRVWUA. SRP is governed by a complex combination of boards and councils who, among other responsibilities, establish the various rates associated with the water subject to WDUA and other agreements to be described later in this chapter, as well as the mix of surface and groundwater that constitutes assessment water (the basic allocation of SRP water that is made available by payment of the SRVWUA assessments for each acre of eligible land).

Unlike the CAWCD, water rates for SRP lands are established on an annual basis, along with the mix of water allocated as assessment water. For calendar year 2009, the assessment water for SRP eligible lands was set at 2 AF/acre of stored water (surface water). No developed water (groundwater) was included in the base assessment. Additional assessment water can and has been made available during wetter years, including additional stored/developed water and other classes of water (pump right water, spillwater, and dollar water) at various assessment levels and rates. Due to favorable water storage conditions within the SRP reservoir storage system, an additional 1 AF/acre of stored water was made available to eligible lands in 2009, making the total stored water available to SRP eligible lands 3 AF/acre.

These allocations can be adjusted as the year progresses based on watershed and runoff conditions. In addition to specific administrative charges provided under the WDUA, the assessment fee for 2009 was set at $27.50 per acre of eligible land. Payment of this fee provided for the delivery and use of up to the 2 AF of assessment water. The third AF of additional assessment water was made available at an additional charge.

2.6.2. Water Transportation Agreement

A water transportation agreement authorizes cities to transport non-SRP water through the SRP water delivery system. The agreement establishes the mechanism for the rates,

fees, and charges associated with moving water in the SRP facilities and also includes specific water loss accounting provisions. The fee for this service is adjusted annually for inflation, and the number is unpublished. The cities are notified of the rate on an annual basis.

The City's water transportation agreement was executed on September 27, 1991 and authorizes the City to transport non-SRP water (excluding reclaimed water which is currently prohibited in SRP canals) through the SRP water delivery system. CAP water delivered to the Avondale Recharge Facility through the SRP water delivery system is subject to the terms of this agreement. The agreement is in effect through June 30, 2041.

In order to deliver CAP water through the SRP system, Avondale must use capacity in the Central Arizona Project/Salt River Project Interconnection Facility (CSIF). The City is currently working to renew its agreement for capacity in the CSIF. Capacity in the CSIF can be made available on a lease basis. The costs for use of the facility are based upon a combination of factors and are determined at the time a lease of capacity is requested.

2.6.3. New River Agua Fria River Underground Storage Project Agreement

This agreement provides the ability for a contractor with SRP to store water in its New River Agua Fria River Underground Storage Project (NAUSP). The agreement quantifies the storage entitlement; provides for the cost of use for the facility; and sets pre-agreement charges, other charges (including rates for storing reclaimed, SRP, and CAP water), and lease charges for leases of capacity.

The City executed this agreement with SRP on August 4, 2004, and the agreement is effective for fifty years from the date of issuance of the initial underground storage facility permit. The agreement states that the City shall have 10 percent of the storage entitlement. The agreement provides for the cost of use for the facility, pre-agreement charges, other charges (including rates for storing reclaimed, SRP, and CAP water), and lease charges for leases of capacity.

2.6.4. Paired Well Agreement

Special agreements can be established with SRP. One such agreement is called a paired well agreement. A paired well agreement can be a letter agreement between SRP and a city providing for the design, installation, and construction of a new paired well subject to the terms of the WDUA. The agreement allows for a new well to be constructed within 660 feet of an existing SRP well that remains in service to make SRP water deliveries, and the new paired well will deliver water to city potable water service.

A paired well agreement between SRP and the City of Avondale for Well #17 was executed on August 29, 2003. The agreement provides the City with the right to use up to 2,461 AFY of water from Well #17, subject to the review and approval by ADWR.

2.7. City Programs

The City has a policy that requires developers who have lands within the City service area with Irrigation and Type 1 Non-Irrigation Grandfathered Groundwater Rights to extinguish the rights and pledge the resulting AWS (also known as extinguishment) credits to the City's AWS account. The City also requires that developers must "cut over" the SRP water deliveries to the City's domestic water account so the City can receive the SRP water on behalf of the landowners and deliver it to them as potable water through the City delivery system. The guiding principles for this policy are based upon provisions of the City's WDUA with SRP.

2.7.1. Ordinances

Avondale has a Drought Ordinance and a Drought Plan that provide measures to reduce water consumption during drought or infrastructure failure. There are four stages of drought identified with corresponding measures and specific water reduction goals:

- Drought Stage I (Water Watch) – 5 percent reduction goal: When estimated annual water demand exceeds renewable water supplies or when a regional drought condition has caused nearby municipalities to declare similar drought stage restrictions.
- Drought Stage II (Water Alert) – 10 percent reduction goal: When the estimated annual water demand exceeds renewable water supplies by 10 percent or when water demand is greater than safe production capability for more than three consecutive days.
- Drought Stage III (Water Warning) – 15 percent reduction goal: When the estimated annual water demand exceeds renewable water supplies by 15 percent or when water demand is greater than safe production capability for more than two consecutive weeks.
- Drought Stage IV (Water Emergency) – 30 percent reduction goal: When the estimated annual demand exceeds renewable water supplies by 30 percent or when water demand exceeds total production capability for more than four consecutive weeks.

The City Council is authorized under the Drought Ordinance to declare drought stages by resolution. The City has published a web page that describes and provides links to several drought-related resources: the Drought Plan, a matrix that outlines each drought stage, specific measures for achieving the related demand reduction goals, a brochure describing the drought ordinance, and water conservation measures available to water users. In addition, water conservation resources are available from the City's water conservation office. Additional ordinances address water waste and water conservation.

2.7.2. Water Conservation Program

The City also has a water conservation program encouraging efficient water use with a goal of stretching the City's water supplies where possible. A brief description of the City's water conservation program, consisting of rebate programs and services, conservation ordinances, education programs, and outreach programs, is included in Appendix A. *The City is in compliance with all conservation requirements associated with ADWR's Third Management Plan.*

2.8. Well Spacing and Well Impact Rules

In accordance with ADWR's Well Spacing Rules (A.A.C. R12-15-1302), a proposed new well or wells may not cause an additional 10 feet or more of drawdown on an existing "well of record" during the first five years of operation. The applicant may submit a hydrological study to assist ADWR in making a determination of potential impacts of a new well on existing wells. If ADWR determines that a proposed well will result in unreasonable drawdown, the applicant has the option to acquire signed and notarized consent forms from the owner of the well of record consenting to the withdrawals from the proposed well or wells. However, this type of consent is often unattainable, potentially costly, and/or time consuming. The other options to mitigate potential drawdown impact are to reduce the proposed pumping rate or relocate the proposed well or wells.

As a result of the these rules, the City must consider the proximity of existing non-City owned wells when identifying locations for new production wells, and the City will need to conduct well impact assessments to evaluate the potential drawdown effects on adjacent, non-City owned wells.

2.9. Water Reuse Regulations

Several regulations govern the direct and indirect use of reclaimed water as a water resource. The regulations are summarized below; the City's 2005 Reclaimed Water System Master Plan provides additional details on how each of these regulations is considered and addressed by the City.

- **Aquifer Protection Permit (APP).** The APP (A.R.S. § 49-241 through 49-252 and A.A.C. R18-9-101 through R18-9-403) is needed by any facility that discharges pollutants in a manner such that there is a reasonable probability that the pollutant will reach the aquifer. The discharge can either be directly to the aquifer or to the land or vadose zone above an aquifer. For wastewater treatment facilities, the APP program requires facilities to obtain an individual APP and to use best available demonstrated control technology to achieve the greatest degree of discharge reduction determined for a facility. *The City's water reclamation facility (WRF) and recharge facility each have an APP. The permit numbers with ADEQ are P-100573 and P-105889, respectively.*

- **National Pollutant Discharge Elimination System Permit (NPDES).** The NPDES program in Arizona is operated by ADEQ as the AZPDES permit program. The AZPDES permit program (A.A.C. Title 18, Section 9) establishes water quality requirements for water reclamation facilities that discharge to watercourses in Arizona and enforces the requirements through monitoring and reporting. Federal Clean Water Act mandates and State surface water quality standards are used to develop plant-specific discharge standards for NPDES permits. *The Avondale WRF has an AZPDES permit (No. AZ0023281), which covers any City water reuse opportunities resulting in discharge or recharge in a waterway or regional recharge.*
- **ADEQ Reuse Regulations.** The ADEQ reuse regulations (A.R.S. §§ 49-104 (B)(13) and 49-141; 18 A.A.C. 9, Art. 6 and 7; and A.A.C. Title 18, Chapter 11, Article 3) identify beneficial means of reuse and identify the minimum reclaimed water quality requirements for each use. Five classes of reclaimed water and the allowable irrigation uses (e.g., golf courses, parks, highway landscaping, cemeteries, common areas, school grounds, and residential lawns) are stipulated in the rules. Other uses (e.g., creating artificial lakes and other recreational features, cleaning streets, irrigating crops, and using in fire protection systems) are also permitted under the regulations. *If the City implements a reuse program that includes direct use, reclaimed water permits that include monitoring and reporting at the WRF will be needed. In addition, each end user will need a Type 2 general permit, or the City will need a Type 3 general permit, to act as a reclaimed water agent for multiple end users.*
- **Underground Storage and Recovery of Reclaimed Water.** A general description of the Underground Storage and Savings Program was provided in Section 2.3. Until 2025, reclaimed water may also be stored and can accrue water credits through direct underground storage or groundwater savings resulting from the use of reclaimed water. Stored water may either be used on an annual basis or credited to a long-term storage account. Excess water at the end of the calendar year may be credited to the storer's long-term storage account. The reclaimed water provider can recover the groundwater anywhere within its service area. The recovered water is administered as reclaimed water by ADWR when recovered within the area of hydrogeologic influence and is not counted in the calculation of gallons per capita per day (gpcd) municipal conservation requirements. The major advantage to the reclaimed water provider is a conversion of its non-potable reclaimed water resource to potable groundwater on a one-for-one basis. Recovery of long term storage credits is not subject to typical five percent "cut to aquifer." *The Underground Water Storage, Savings, and Replenishment Program provides the City an opportunity to receive storage credits for either direct underground storage of reclaimed water or groundwater savings due to the use of reclaimed water.*
- **Water Storage and Recovery Permits.** When stored water is recovered, it must be recovered in a well that is permitted as a recovery well and must be used in a manner that is consistent with the water use prior to storage. Reclaimed water that has been treated at a WRF can be used in any portion of the service area after recovery. *The Avondale Recharge Facility has an Underground Storage Permit (No. 71-565257)*

allowing it to accrue credits for recharged water. Pursuant to its most recent recovery well permit dated November 2, 2009, all of Avondale's wells have been permitted as recovery wells.

- **Water Exchanges.** As described previously, water exchanges involve the exchange of one water supply for another, either to avoid the costs of physically moving water or to match water supplies of varying qualities with appropriate uses. Utilizing canals for water exchanges involving reclaimed water is currently only permitted if the canal water is only used for non-potable applications. *Currently, the City is not using reclaimed water in any exchanges.*
- **Clean Water Act Section 404.** Section 404 of the Clean Water Act establishes a permitting program to regulate excavation in waters of the United States. The program is jointly administered by United States Environmental Protection Agency (USEPA) and the US Army Corps of Engineers (USACE) with advisory input from U.S. Fish & Wildlife, National Marine Fisheries Services, and State Agencies, such as ADEQ, ADWR, and Arizona Game and Fish. The 404 permit is issued by the USACE, and certification is required by the State. *If the City decides to pursue a recharge opportunity that intercepts or infringes on a United States waterway, the 404 permitting process will be triggered, and a USACE 404 permit may be required.*
- **208 Water Quality Management Plan.** Section 208 of the Clean Water Act requires regional planning agencies to develop comprehensive Water Quality Management Plans (WQMPs) that assure the State's water quality standards will be consistently maintained. These plans identify existing and proposed wastewater treatment facilities to meet the anticipated municipal and industrial waste treatment needs of an area over a 20-year period and provide general planning guidance for non-point source, sludge, storm water, and other activities. When construction projects, State Revolving Fund loans, or certain types of permit applications are submitted to ADEQ, the proposal must be reviewed through the State Continuing Planning Process (CPP) for plan consistency. The CPP covers WQMP approval and amendment processes and includes a discussion of permits and programs required to maintain consistency with the certified regional WQMP. A facility that is not consistent with the 208 WQMP will be required to develop an amendment to the current 208 Regional Plan in their area, and the amendment must be approved by a public process. Inclusion of plans in the 208 WQMP is a prerequisite to obtain an NPDES permit. *The Avondale WRF is included in the 2002 Maricopa Association of Governments (MAG) 208 Water Quality Management Plan Update. The plan also includes the potential Northside WRF located north of Interstate-10 with a future capacity of 6 million gallons per day (mgd) and a 1 mgd package plant to treat wastewater south of the Gila River.*

2.10. Safe Drinking Water Act

Passed by Congress in 1974, the intent of the Safe Drinking Water Act (SDWA) is to protect public health by regulating the nation's public drinking water supply. The SDWA authorizes the USEPA to set health-based national standards for drinking water quality to

protect against both naturally-occurring and synthetic contaminants that may be found in drinking water. In addition to the health-related primary drinking water regulations, the SDWA also authorizes USEPA to develop secondary regulations for contaminants that may adversely affect the aesthetic quality of drinking water. Secondary standards are non-enforceable guidelines.

With the exception of the secondary standards, which have not been adopted, Arizona's AAC Title 18 regulations follow the SDWA requirements. The Arizona Department of Environmental Quality (ADEQ) is currently in the process of changing Title 18 to incorporate the SDWA regulations by reference, rather than providing a state-specific interpretation of the regulations.

As a public water system, the City of Avondale must adhere to the requirements of the Safe Drinking Water Act. Some of the key federal standards and regulations governing surface and groundwater systems are listed in Table 2-1. For current regulations, the published date is listed; for future regulations, proposed dates are shown. Table 2-1 also indicates whether a specific regulation currently applies to the City system and whether it will apply in the future. Unless the City incorporates surface water in the future, only the regulations for groundwater systems will apply.

A brief summary of the regulatory requirements of the existing rules listed in Table 2-1 is provided below.

- **Maximum Contamination Levels (MCLs).** There are currently over 90 contaminants within inorganic chemicals (IOCs), volatile organic chemicals (VOCs), synthetic organic chemicals (SOCs), radionuclides, and disinfection byproducts (DBPs) that require monitoring by a public water system (PWS).
- **Stage 1 Disinfectants and Disinfection Byproducts Rule (D/DBPR).** The Stage 1 D/DBPR is aimed at improving public health protection by reducing exposure to DBPs. This rule establishes limits for disinfection residuals and DBP formation and may require conventional treatment plants to employ enhanced coagulation to achieve total organic carbon (TOC) removal to help reduce DBP formation in the system.
- **Stage 2 Disinfectants/Disinfection By-Products Rule.** The Stage 2 D/DBPR aims to further reduce public exposure to DBPs by establishing new MCL goals for certain DBPs and basing DBP compliance on locational monitoring at individual distribution system sites instead of system-wide monitoring. Monitoring locations, particularly for high-DBP areas of the system, are identified by an Initial Distribution System Evaluation program.
- **Surface Water Treatment Rule.** For surface water treatment systems, the Surface Water Treatment Rule establishes requirements for *Giardia* and virus removal, turbidity standards, and disinfectant residual in the distribution system. The rule also applies to groundwater systems that are deemed groundwater under the direct influence of surface water.

Table 2-1:
Drinking Water Regulation Applicability

Regulation	Final Rule Date	Applicability		
		Current Groundwater System	Future Groundwater System	Future Groundwater and Surface Water Systems
MCLs for IOCs, VOCs, SOCs, Radionuclides, and DBPs	1976 - current	X	X	X
Stage 1 D/DBP Rule	1998	X	X	X
Stage 2 D/DBP Rule	2006	X	X	X
Surface Water Treatment Rule	1989			X
Interim Enhanced Surface Water Treatment Rule and Long-Term 1 Enhanced Surface Water Treatment Rule	1998 and 2002			X
Long Term 2 Enhanced Surface Water Treatment Rule	2006			X
Filter Backwash Recycling Rule	2001			X
Total Coliform Rule	1989	X	X	X
Lead and Copper Rule	1991	X	X	X
Arsenic Rule	2001	X	X	X
Groundwater Rule	2007	X	X	
Unregulated Contaminant Monitoring Regulation	1999 - current	X	X	X
Total Coliform Rule Revisions and Distribution System Rule	2011-2012	X	X	X
Radon Rule	TBD[1]	X	X	X

Note:
(1) To be determined.

- **Interim Enhanced Surface Water Treatment Rule and the Long Term 1 Enhanced Surface Water Treatment Rule.** The Interim Enhanced Surface Water Treatment Rule focuses on further protections against microbial contaminants for systems serving greater than 10,000 people, and the Long Term 1 Enhanced Surface Water Treatment Rule applies these same requirements to systems serving fewer than 10,000 people. These rules establish requirements for *Cryptosporidium* removal, turbidity monitoring and standards, and DBP profiling and benchmarking for water treatment systems that exceed certain DBP concentrations. The rules also prohibit construction of new uncovered finished water storage facilities.
- **Long Term 2 Enhanced Surface Water Treatment Rule.** The purpose of the Long Term 2 Enhanced Surface Water Treatment Rule is to reduce illness linked with *Cryptosporidium* and other microorganisms in drinking water. The rule supplements existing regulations by targeting additional *Cryptosporidium* treatment requirements to higher risk systems. The rule establishes requirements for initial monitoring to determine treatment requirements, treatment based on monitoring, covering of

uncovered finished water reservoirs or treatment for virus, and benchmarking current level of microbial treatment before making significant changes in disinfection practices.

- **Filter Backwash Recycling Rule.** The Filter Backwash Recycling Rule adds new requirements for conventional and direct filtration plants to ensure that recycle streams are properly treated.
- **Lead and Copper Rule.** The Lead and Copper Rule establishes action levels for lead and copper. Exceeding the action level is not a violation but may trigger additional sampling, corrosion control treatment, and public notification and/or education.
- **Arsenic Rule.** The Arsenic Rule applies to groundwater sources as well as to surface water sources and reduces the arsenic MCL from 0.050 to 0.010 milligrams per liter (mg/L).
- **Unregulated Contaminant Monitoring Regulation.** USEPA uses the Unregulated Contaminant Monitoring Regulation to collect data for contaminants suspected to be present in drinking water but that do not have health-based standards set under the SDWA. Every five years USEPA reviews the list of contaminants, largely based on the Contaminant Candidate List. The Unregulated Contaminant Monitoring Regulation incorporates a tiered monitoring approach and establishes classified lists of contaminants to be monitored by specified groups of utilities.
- **Groundwater Rule.** The Groundwater Rule became effective in January 2007, with compliance beginning December 1, 2009. The Groundwater Rule provides increased protection against microbial pathogens in public water systems that use groundwater. The Groundwater Rule establishes requirements for periodic sanitary surveys of groundwater systems, triggered source water monitoring when a water system identifies a positive sample during Total Coliform Rule monitoring, corrective actions, and compliance monitoring to ensure treatment technologies reliably achieve virus removal.
- **Total Coliform Rule Revision and Distribution System Rule.** The original Total Coliform Rule set the total coliform standard based on the presence or absence of the total coliform bacteria rather than the bacterial density. USEPA is currently revising the Total Coliform Rule. The revision focuses on assessing the effectiveness of the current TCR in reducing public health risk and the possible use of more economic-effective alternatives or additional monitoring strategies that would maintain or improve public health protection. USEPA is also considering a Distribution System Rule that would incorporate some of the components of the TCR.
- **Revised Unregulated Contaminant Monitoring Regulation 3.** In February 2008, USEPA released the draft Contaminant Candidate List 3 that will be considered for possible monitoring and regulation.
- **Radon Rule.** When finalized, the Radon Rule will establish an MCL for radon and will require monitoring at each entry point to the system.

3. Existing Water Supplies

This chapter presents a summary of the City's existing water supply portfolio as outlined in its existing Designation of Assured Water Supply with ADWR and as updated in its recent application for Modification of a Designation of Assured Water Supply. Both of these documents describe water supplies that are physically, legally and continuously available to supply the City's projected water demands for a minimum of 100 years.

3.1. Existing Designation of Assured Water Supply

The City received its initial AWS Designation in 1999. The provisions of the initial Designation of Assured Water Supply are contained within the Decision and Order No. 26-002003 signed by the Director on August 16, 1999. The initial designation recognized that the volume of water available to the City to meet the City's projected and committed demands for 2010 is physically, legally and continuously available for 100 years. The assured water supplies included in the City's initial designation included SRP entitlement water, CAP subcontract water, and groundwater through its groundwater allowance, incidental recharge, and membership in the CAGRD.

On June 11, 2007, the City applied to ADWR to modify its initial Designation. The request was made so that the designation would include additional CAP allocations that had been assigned to the City and additional production well capacity that had been constructed since the initial designation. The provisions of the modified Designation of Assured Water Supply are contained within the Decision and Order No. 86-002003.0001 signed by the Director on March 24, 2008.

The modified designation recognizes that the volume of water available to the City to meet the updated projected and committed demands for 2010 of 21,186 AF is physically, legally, and continuously available for 100 years. The assured water supplies included in the City's modified designation included SRP entitlement water, CAP subcontract water, and groundwater through its groundwater allowance, incidental recharge, and membership in the CAGRD. Table 3-1 summarizes the approved water supplies in the City's modified (existing) designation.

Table 3-1:
Existing Avondale Designation of AWS Approved Water Supplies

Source	Approved Supply (AFY)	Comments
Groundwater Replenished by CAGRD	13.148.04	__
Groundwater Incidental Recharge	515.65	Incidental recharge factor = 4.43 percent of previous year's demand. Approved volume is for 2006 water demand.
Groundwater Allowance	547.31	Groundwater allowance balance as of date of Decision and Order spread over 100 years.
Subtotal	**14,211**	Based on demonstration that after14,211 AFY of pumping for 100 years, the groundwater level will not drop below 1,000 feet below ground surface.
CAP Allocations	5,416	To be recharged and recovered within the area of impact of storage. Can be used anywhere in the service area.
SRP Entitlements	8,463	To be recharged at the Avondale Recharge Facility and recovered within the area of impact of storage. To meet On-Project Area demands only.
Subtotal	**13,879**	Available well capacity within the area of impact of storage = 17,589 AFY
Total Physically Available	**28,090 AFY**	
Projected 2010 Demand	**21,186 AF**	

Source: Department of Water Resources, AWS-2007-012, Decision and Order No. 86-002003.0001, March 24, 2008.

It should be noted that certain information contained in the City's AWS documentation was based on information available at the time the documents were applied for, including production well capacities, water demands, reclaimed water availability, etc. This information has been updated or modified for the purposes of this Water Resource Master Plan update and, in many instances, will not match the information contained in the AWS documentation.

3.1.1. Salt River Project

Pursuant to the Water Delivery and Use Agreement with SRP, the City has access to the SRP water entitlements as agent for the lands entitled to water from the SRP. The City is required to account for water deliveries such that water from SRP must only be used on lands that are eligible to receive SRP water.

In considering SRP water as an assured water supply, ADWR accepted a report prepared by SRP entitled SRP Assured Water Supply Study for Salt River Project Member Lands (SRP, 1995). The SRP study evaluates the availability of the supply and allocates it among water providers. The allocations were not necessarily indicative of the value or priority of rights within each service area, but were based on projected build-out of On-Project Area lands. The supply determined available to Avondale was 8,463 AFY. The SRP water was to be recharged at the Avondale Recharge Facility.

3.1.2. Central Arizona Project

For assured water supply purposes, CAP subcontracted water is considered physically, legally, and continuously available to the subcontractor for 100 years. For providers, such as Avondale, that operate under an interconnect agreement with SRP for delivery of its CAP water, it is assumed that sufficient canal capacity exists to meet demands for direct delivery. The City's initial Designation included its initial CAP M&I allocation of 4,099 AFY. Since approval of the initial Designation, the City acquired an additional 647 AFY of CAP M&I allocation water from an assignment of a portion of the McMicken Irrigation District subcontract, and an additional 670 AFY from an assignment of a portion of the Liberty Water Company (formerly Litchfield Park Service Company) subcontract. The City's total CAP allocation is currently 5,416 AFY.

The City currently delivers its CAP water for storage to the CAWCD's Agua Fria and Hieroglyphic Mountains regional recharge and storage facilities. The City also has the ability to take direct delivery of CAP water at its recharge facility and at the SRP NAUSP facility via the CSIF and the SRP canal system.

3.1.3. Groundwater

Three categories of groundwater allowance were considered as assured water supplies: a basic phase-in allowance, an incidental recharge allowance, and credits from extinguishment of groundwater rights. The City's modified Designation of AWS included the following groundwater allowances:

- Phase-in Allowance: the rules allowed a small quantity of groundwater to be pumped to allow providers time to "phase-in" renewable supplies. The allowance was determined by multiplying the provider's 1994 demand by a prescribed 7.5 factor. The modified designation considered the groundwater allowance balance as of the date of the Decision and Order of 54,731.47 AF, or 547.31 when averaged over 100 years.
- Incidental Recharge: incidental recharge consists of water returning to the aquifer after it has been beneficially used. Under the rules, incidental recharge is calculated by multiplying the provider's previous year demand by a standard factor of 4 percent for the Phoenix AMA. A higher factor may be allowed to account for turf-related facilities served by the provider. ADWR allowed an increased incidental recharge rate for Avondale of 4.43 percent. On this basis, the modified designation included an incidental recharge volume for Avondale of 515.65 AFY based on the water demand for calendar year 2006.
- Extinguishment Credits: these credits can be included through permanent extinguishment of an Irrigation Grandfathered Right or a Non-Irrigation Grandfathered Right (Type 1 or Type 2). Avondale had not applied for any extinguishment credits prior to the modified designation.

ADWR evaluates the physical availability of underground supplies by considering groundwater allowances, storage credits (existing and anticipated), and projected pumping and recharge by the provider over 100 years. If, based on use of a groundwater model, ADWR determines that the expected pumping by the provider and others in the region will not result in the depth to groundwater dropping to below 1,000 feet, the requested volume of pumping pursuant to the designation can be authorized. ADWR determined that the City has sufficient existing and projected well capacity for the amount of groundwater demand anticipated (14,211 AFY over 100 years), and that the depth to water criteria will be met with the City's anticipated recharge and pumping rates.

3.1.4. CAGRD

As indicated in Section 2, the rules allow a provider to meet the consistency with the AWS management goals by applying for membership in the CAGRD. Because CAGRD membership allows a provider to continue pumping groundwater from within its service area with no assurance that water will be physically replenished in that area, the groundwater physical availability criterion must be met to pledge the CAGRD source toward an assured water supply. By virtue of its agreement with CAGRD and demonstration of physically available groundwater, ADWR approved an additional assured water supply of 13,148.04 AFY in the City's modified Designation of AWS. Beginning in 1999, the City was required to report a minimum amount of excess groundwater use for replenishment or the amount of groundwater in excess of their allowable groundwater use, whichever is greater.

3.2. Application for Re-designation of Assured Water Supply

On October 10, 2008, the City complied with requirements to submit an Application for Modification of its Designation of Assured Water Supply. The AWS rules allow the City to project water demands based on projected population and a per capita demand factor. For purposes of the application, the City used a water demand factor of 200 gallons per capita per day (gpcd) applied to the most recent population projections, and calculated a demand of 27,604 AF in 2029, hence an estimated 100 year demand of 2,760,400 AF. ***As indicated earlier, this Water Resource Master Plan will update or modify certain information or assumptions included in the AWS documentation such as production well capacities, water demands, reclaimed water availability, etc.*** Table 3-2 summarizes the water supplies that the City has pledged to meet this projected demand.

The basis for the pledged supplies in the City's application for re-designation is briefly described below. These anticipated future supplies will be updated with current information in later sections of this Water Resource Master Plan.

Table 3-2:
Pledged Water Supplies for Re-designation

Sources of Supply	100 Year Volume (AF)
Ground water (Groundwater Allowance and Incidental Recharge)	68,896.45
Central Arizona Project	541,600
Surface Water (SRP)	1,339,800
Reclaimed Water	1,353,880
Other (Long Term Storage Credits)	41,667.47
Total 100-Year Volume	**3,345,843.92**

Source: City of Avondale, Designation or Modification of Designation of Assured Water Supply Application, October 30, 2008.

- Groundwater: this amount includes the City groundwater allowance balance of 55,135.72 AF as of May 2008, according to the ADWR Groundwater Allowance Balance (May 2008), and calculated incidental recharge based on a factor of 4.43 percent.
- Central Arizona Project: this amount was based on the City's current CAP allocation of 5,416 AFY.
- Surface Water (SRP): this amount was based on a report by SRP provided to ADWR entitled 2008 Assured Water Supply Study for Salt River Project Member Lands (Draft, October 15, 2008) which is an update to the 1995 SRP report. In summary, SRP anticipates that it can supply enough stored and developed water and normal flow water to satisfy the City's projected 2030 On-Project Area demand of 13,398 AF for a minimum of 100 years. The SRP estimates are based on the assumption that by 2030, all of the agricultural member lands will have been cut over to the City.
- Reclaimed Water: this amount is based on the City's estimate of 100 years of reclaimed water production. The estimate was based on commencement of reclaimed water recharge in 2009, 45 percent of the projected water demand converting to reclaimed water, and that the City would commit to continue discharging 1,120 AFY of reclaimed water to the Agua Fria River to maintain a wetlands habitat downstream of its WRF. The estimate also assumed that the City would build out by 2040 (i.e., that reclaimed water production would remain constant after 2040).
- Other (Long Term Storage Credits): this amount was the City's long term storage account balance of 41,667.47 AF according to the ADWR's 2007 Long Term Storage Account Summary (December 13, 2007).

Thus, as presented in the application for re-designation, the City's pledged water supplies totaling 3,345,843.92 AF over 100 years is sufficient to satisfy the projected 100-year demand of 2,760,400 AF. A decision by ADWR regarding this application has not been formally transmitted to the City. The City's existing (modified) Designation of AWS is considered in effect until a final determination based upon the current application is issued by ADWR.

THIS PAGE INTENTIONALLY LEFT BLANK

4. Water Supply System and Water Quality

This chapter provides a description of the features of the City's water resources system, including the service providers (water and wastewater), existing infrastructure (drinking water and reclaimed water facilities), and the quality of water supplies.

4.1. Service Providers

4.1.1. Water Service Providers

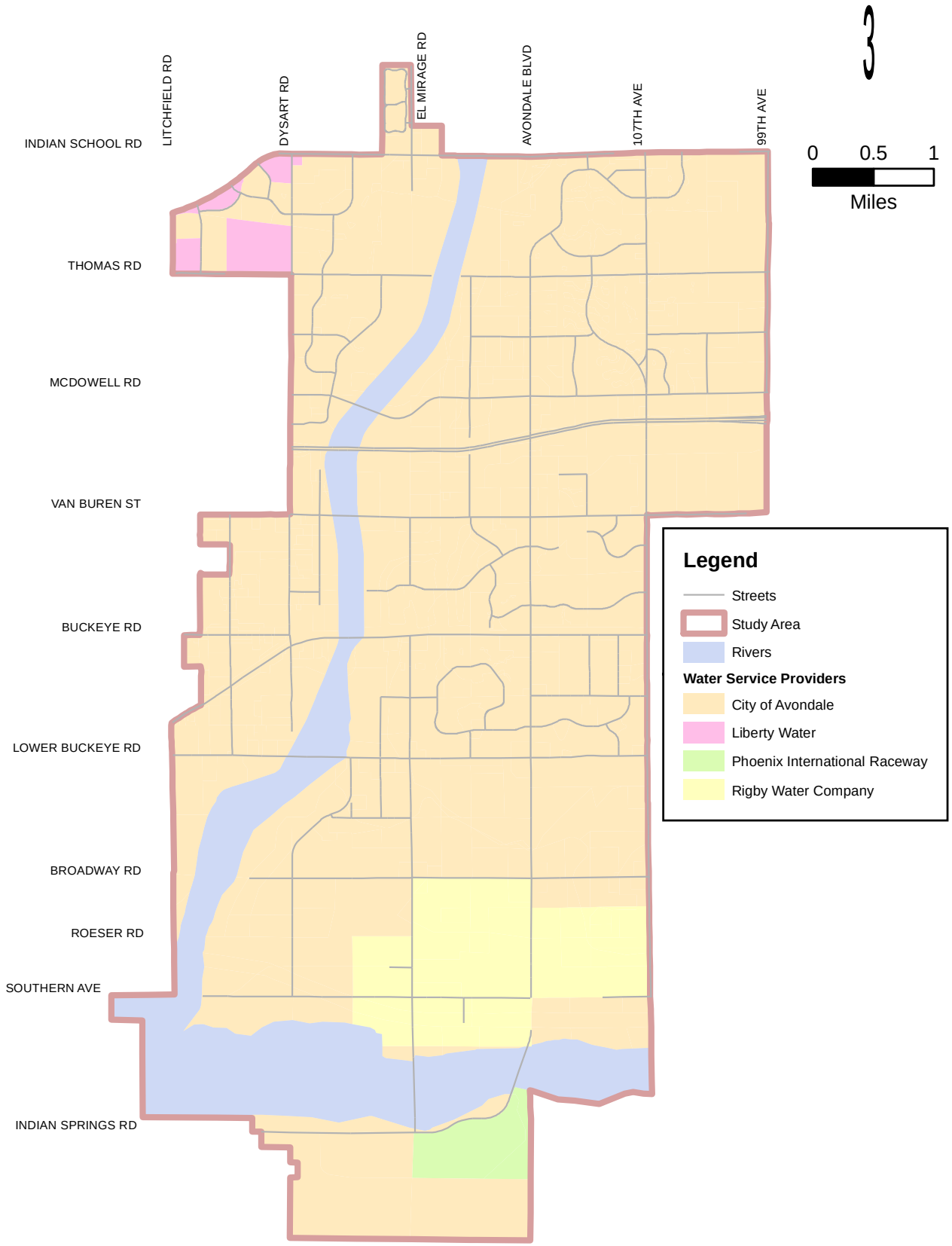
The City is the water service provider for the majority of the area within the study area (Figure 4-1) with the following exceptions:

- The Liberty Water Company (formerly Litchfield Park Service Company) serves four small areas within the area bounded by Thomas Road, Litchfield Road, Dysart Road, and Indian School Road. Liberty Water Company supplies non-residential customers in this area which include a college, some schools, and a few commercial properties.
- Rigby Water Company serves an area of approximately 2.5 square miles in the south-eastern portion of City. The system is divided into two independent systems and has four wells. The City is currently in the process of purchasing the Rigby Water Company; the system will maintain current operational practices during the acquisition period.
- Phoenix International Raceway (PIR) is not a municipal water service provider; however, it is a self-supplier with its own water source and infrastructure to use water on the PIR site.

The City does not plan to provide water services within the Liberty Water service area, thus this service area is excluded from the demand projections in this Water Resource Master Plan update. The City does, however, anticipate serving the Rigby Water Company service area and the PIR at some time in the future, and their demands are included in the demand projections herein.

4.1.2. Wastewater Service Providers

The City has the right to provide wastewater service to the majority of the study area (Figure 4-2). The City does not plan to provide wastewater service to isolated areas that have and plan to remain on septic systems and to the Liberty Water Company service area. All wastewater currently generated within the City wastewater service area is conveyed by the sewer collection system to the WRF at the Charles M. Wolf Water Resource Center.



M:\0864025\GIS\MXDs\WRMP Final Report\Figure 4-1 Water Service Providers.mxd

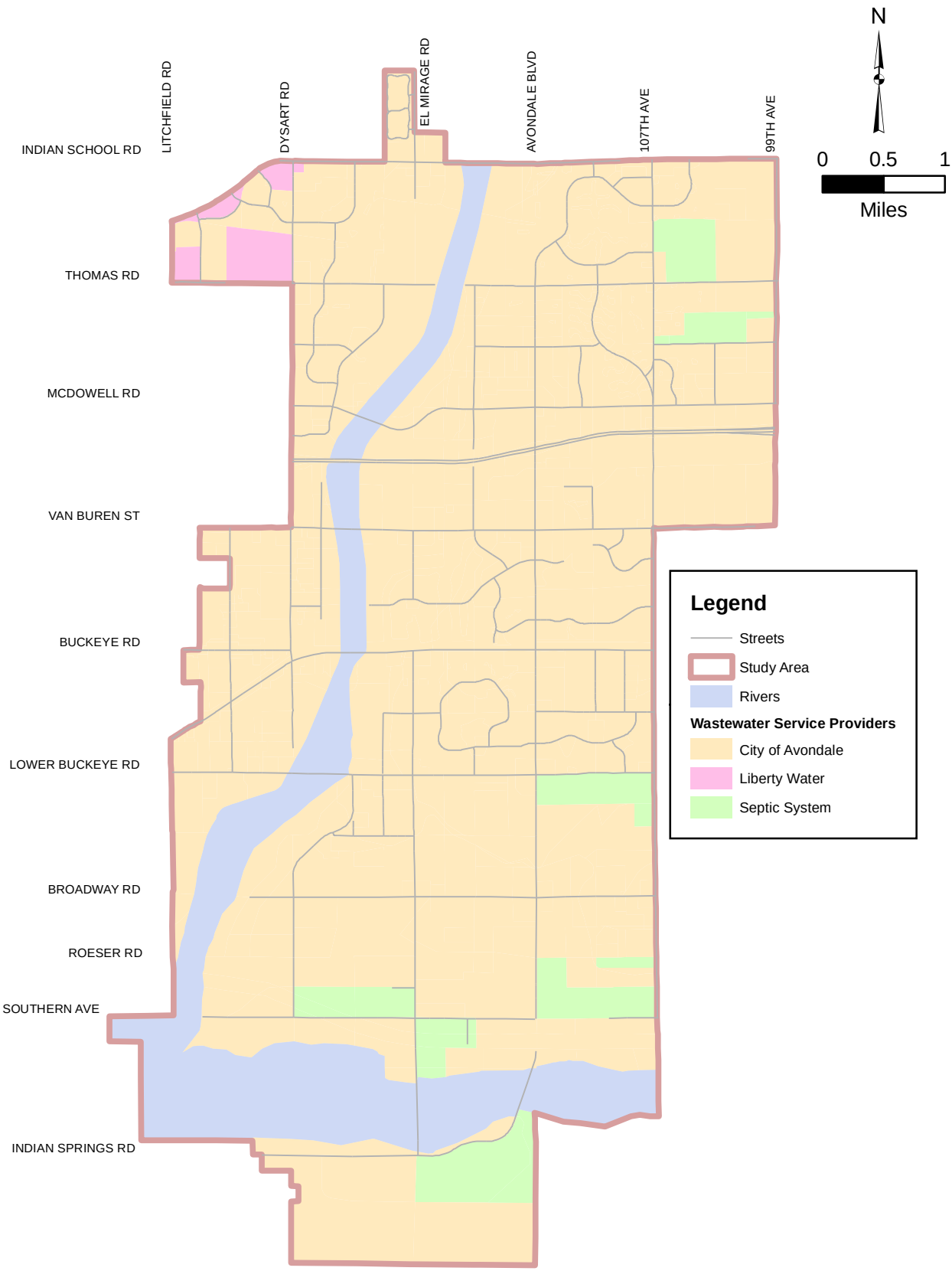
CITY OF AVONDALE, ARIZONA
WATER RESOURCE MASTER PLAN

Water Service Providers

MALCOLM PIRNIE

May 2010

FIGURE 4-1



M:\0864025\GIS\MXDs\WRMP Final Report\Figure 4-2 Wastewater Service Providers.mxd

CITY OF AVONDALE, ARIZONA
WATER RESOURCE MASTER PLAN

Wastewater Service Providers

MALCOLM PIRNIE

May 2010

FIGURE 4-2

The PIR is currently on a septic system, but will be served by the City in the future. The other areas of the City that have septic systems include: the area served by Rigby Water Company; Pecan Groves Trailer Park; the one-acre lots in the area bounded by Lower Buckeye Road, Miami Road, 107th Avenue, and Avondale Boulevard; Glen Arm Farm; county areas north of Encanto Blvd; and homes in the County islands south of the WRF. With the exception of PIR, the City has no plans to provide wastewater service to these areas or to the Liberty Water service area. Thus, no wastewater flows or reclaimed water availability is projected for these areas herein. Projected wastewater flows for the PIR are considered herein.

4.2. Existing Water Infrastructure

The City's existing infrastructure related to water resources and water supply includes groundwater production wells, water supply facilities, water reclamation facilities, and recharge facilities. The facilities, shown on Figure 4-3, are described below.

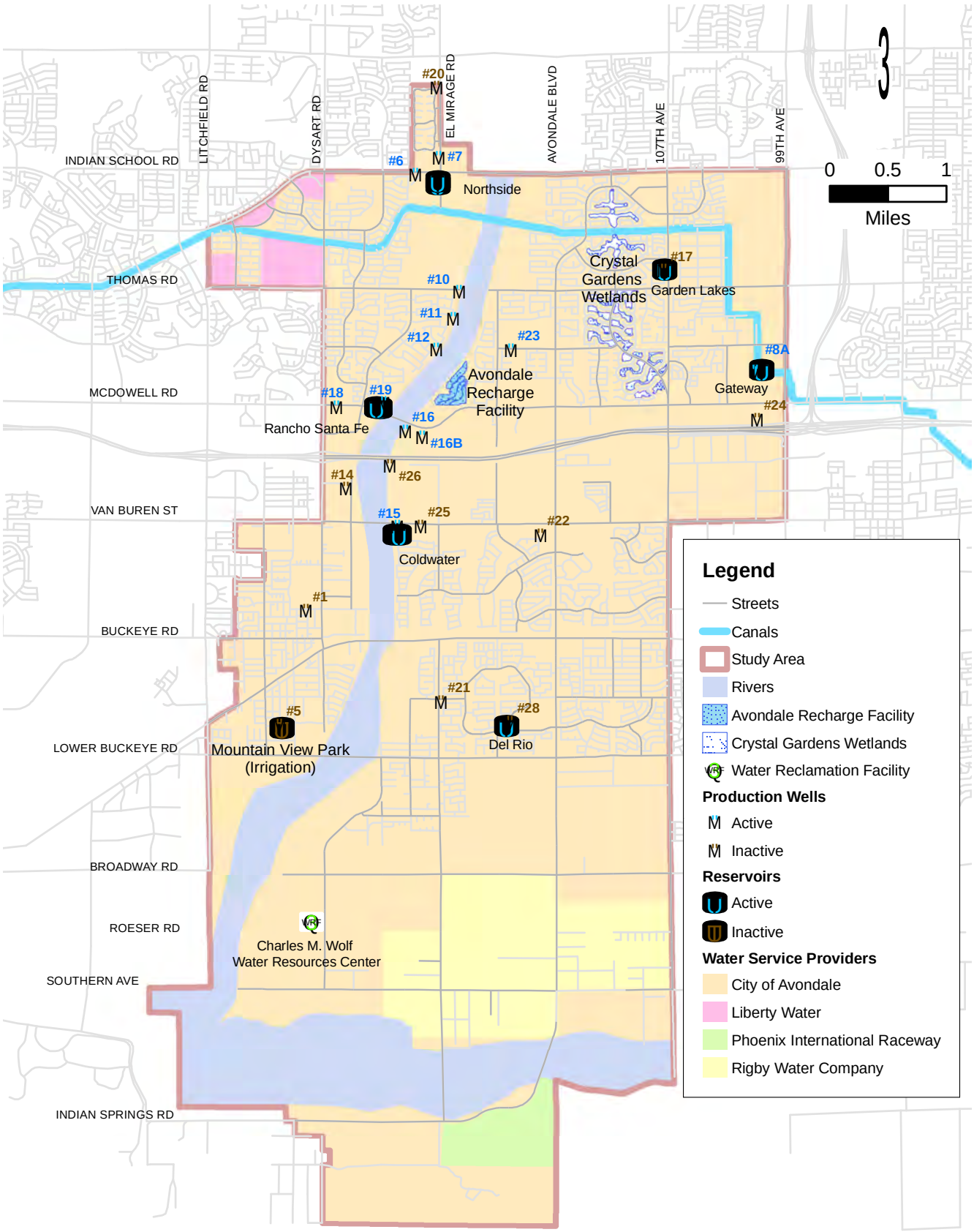
4.2.1. Groundwater Production Wells

The City currently relies on 11 "active" production wells to meet the drinking water needs of the City (Table 4-1). A twelfth active well (Well #16B) supplies irrigation water to Friendship Park and is not connected to the rest of the City's drinking water distribution system. The total pumping capacity of the City's active wells serving the main distribution system (excluding Well #16B) is 26.7 million gallons per day (mgd). The remaining wells owned by the City (termed "inactive) constitute a variety of wells that cannot be operated in their current state. As shown in Table 4-1, reasons for inactivity include under construction, lease expiration, capped, and water quality.

4.2.2. Reservoirs and Treatment Facilities

Nearly all the City wells are pumped to storage reservoirs before the water is distributed (Table 4-2). Well #23 (active) and Well #14 (currently inactive) pump directly to the potable system without storage. The Mountain View Reservoir provides storage only for irrigation uses and currently is filled from the potable distribution system as Well #5 is inactive. The City plans to put Well #5 back into service and remove the irrigation uses from domestic service.

If needed, treatment to reduce various contaminants to below the federally mandated standards for drinking water is also provided. The lease agreement for the Garden Lakes treatment facility expired in December 2009. The lease agreement for the Gateway treatment facility is still valid for another three years; however, this well is operated only during emergencies due to the cost of nitrate treatment. With the recent bankruptcy of the treatment unit vendor, the City is in the process of determining how best to utilize both wells to the extent possible.



\\phoenix\projects\0864025\GIS\MXDs\WRMP Final Report\Figure 4-3 Water Resources Infrastructure.mxd

CITY OF AVONDALE, ARIZONA
WATER RESOURCE MASTER PLAN

Water Resources Infrastructure

MALCOLM PIRNIE

May 2010

FIGURE 4-3

Table 4-1:
Existing Production Wells

Well Registration Number	Well Number	Operation Status	Feed Point	Pumping Capacity (gpm)[1]
55-608731	1	Inactive - Capped	TBD[2]	TBD
55-608733	5[3]	Inactive – Water Quality	Mountain View[3]	275[4]
55-501247	6	Active	Northside	1,550
55-501288	7	Active	Northside	1,550
55-599019	8A	Active	Gateway	2,000[5]
55-608792	10	Active	Rancho Santa Fe	2,200
55-608791	11	Active	Rancho Santa Fe	1,500
55-608793	12	Active	Rancho Santa Fe	2,000
55-583017	14	Inactive – Water Quality	Distribution System	400
55-578749	15	Active	Coldwater	700
55-200566	16	Active	Coldwater	2,200
55-807953	16B[6]	Active	Friendship Park Lake	650
55-201730	17	Inactive – Lease Expiration	Garden Lakes	1,200
55-607157	18	Active	Rancho Santa Fe	2,100
55-588631	19	Active	Rancho Santa Fe	1,450
55-208099	20	Inactive – Under Construction	Northside	1,000[4]
55-203924	21	Inactive – Water Quality	Del Rio	1,820[4]
55-217002	22	Inactive – Under Construction	Coldwater	TBD
55-202404	23	Active	Distribution System	1,260
55-210430	24	Inactive – Under Construction	Gateway	650[4]
55-217001	25	Inactive – Under Construction	Coldwater	TBD
55-618650	26	Inactive – Under Construction	Coldwater	2,200
SRP well	28	Inactive – Under Construction	Del Rio	TBD

Notes:
(1) Pumping capacity was determined by the City using 2009 well pumping records during maximum day.
(2) To be determined.
(3) Water from the Mountain View Reservoir (which is fed by Well #5) is used for irrigation uses only.
(4) Estimated capacity provided by the City.
(5) Treatment capacity (2,000 gpm) limits well (3,000 gpm) production.
(6) Well #16B is used for irrigation uses only.

Table 4-2:
Existing Reservoirs and Treatment Facilities

Reservoir Name	POE #	Supplied By Wells	Status	Total Storage (MG)	Treatment
Rancho Santa Fe (Combined)	4	10, 11, 12, 18, & 19	Drinking	2.8	-
Northside (Combined)	1	6, 7, & 20	Drinking	1.2	Arsenic
Garden Lakes	8	17	Drinking	2.0	Nitrate
Gateway	7	8A & 24	Drinking	1.0	Nitrate & DBCP
Coldwater	5	15, 16, 22, 25, & 26	Drinking	5.0	-
Del Rio	9	21 & 28	Drinking	3.5	-
Mountain View Park[1]	-	5	Irrigation	0.3	-

Note:
(1) Currently filled from the potable distribution system (Well #5 is inactive) and used only to supply water for irrigation uses.

4.2.3. Water Reclamation Facilities

The City's WRF (Charles M. Wolf Water Resources Center) has recently been expanded from a capacity of 6.4 mgd to 9 mgd. The ultimate capacity of the WRF is 15 mgd. The WRF uses an activated sludge process, nitrification/denitrification, and disinfection to produce Class B+ reclaimed water. The City plans to begin pumping most of the reclaimed water from the WRF to the Avondale Recharge Facility through a 24-inch diameter pipeline in 2010. Approximately 1 mgd of reclaimed water flow will continue to be discharged to an outfall in the Agua Fria River to maintain a wetlands area downstream of the WRF. Turnouts are provided on the reclaimed water pipeline for potential future delivery to Coldwater Springs Golf Club and Friendship Park.

4.2.4. Recharge Facilities

The City has access to several recharge facilities (Table 4-3). The City owns and operates the Avondale Recharge Facility, which is located north of McDowell Road and east of the Agua Fria. The facility has a permitted capacity of 13.4 mgd (15,000 AFY) and can be used for recharging surface water (after treatment in the Crystal Gardens Wetlands) and reclaimed water produced at the City's WRF. The City's capacity in NAUSP is owned; however, because the ownership is on a percentage basis, the available recharge capacity at this facility may fluctuate from year to year. The City has not yet used any of its capacity at the NAUSP, but it may begin recharging there by 2015. The City also leases capacity at two CAWCD facilities. Although the total capacity of the CAWCD facilities is large, the amount available to the City on an annual basis may vary at the discretion of CAWCD, based on the requests from all facility participants.

Table 4-3:
Recharge Facilities Available to the City of Avondale

Facility Name	Facility Capacity (AFY)	Capacity Available to Avondale (AFY)	Notes
Avondale Recharge Facility	15,000	15,000	• City-owned • Recharge of surface water and reclaimed water
NAUSP	25,000 in 2009 50,000 in 2010 75,000 in 2011 and beyond	2,500 in 2009 5,000 in 2010 7,500 in 2011 and beyond	• City owns 10 percent capacity in the facility • Recharge of surface water and reclaimed water • Hydraulic capacity of the facility may fluctuate from year to year pending hydrogeologic studies
Hieroglyphic Mountains (CAWCD)	35,000	20,000	• City leases capacity • Facility recharges CAP water • Capacity decided annually by CAWCD
Agua Fria (CAWCD)	100,000	40,000	• City leases capacity • Facility recharges CAP water • Capacity decided annually by CAWCD

4.3. Water Quality

When evaluating water resources, water quality must be considered because of the effect it has on the cost to develop a water source. For example, drilling a well and using groundwater is typically considered less expensive than constructing a surface water treatment plant. However, if advanced treatment for removal of contaminants such as arsenic, nitrate, or total dissolved solids (TDS) is needed, surface water treatment can become comparable or even lower cost than groundwater treatment.

With respect to water quality and treatment, the City strives to have all contaminants less than 80 percent of the federal MCL at the point of compliance. The City also strives to provide water that meets the secondary standards with the exception of TDS, which has a non-enforceable secondary standard of 500 mg/L. The City's treatment goal for TDS is 700 mg/L; however, TDS up to 1,000 mg/L is acceptable under normal conditions. TDS levels above 1,000 mg/L may be warranted under emergency conditions. The water quality for the City's groundwater, surface water, and reclaimed water supplies is summarized below.

4.3.1. Groundwater

All of the City's wells are sampled periodically for several water quality parameters. In addition, samples are collected at each point of entry to the distribution system. The water quality parameters of greatest interest for groundwater systems are arsenic,

fluoride, nitrate, and total TDS. Based on the limited data shown in Table 4-4 (i.e., only one or two data points for each sampling location), fluoride in all wells is below the primary and secondary MCL. However, some wells have arsenic and nitrate exceeding the MCL, and many wells exceed the secondary TDS standard of 500 mg/L. After blending and treating water at the reservoirs, all point of entry data show no compliance concerns with arsenic or nitrate; TDS is still above the secondary standard.

Table 4-4:
Avondale Groundwater Quality

	No. Samples	Arsenic (mg/L)	Fluoride (mg/L)	Nitrate as N (mg/L)	TDS (mg/L)
MCL	**NA**	**0.010**	**4.0**	**10**	**NA**
Secondary Standard	**NA**	**NA**	**2.0**	**NA**	**500**
Well #1	1	0.005	0.19	6.43	**648**
Well #5	-	-	-	-	-
Well #6	2	**0.0219**	0.885	3.095	319
Well #7	2	**0.0328**	1.29	2.02	248
Well #8A	2	0.0026	0.165	**14.8**	**855**
Well #10	2	0.0051	0.28	6.325	**543**
Well #11	2	0.00475	0.255	5.615	**505**
Well #12	2	0.004	0.225	3.97	**549**
Well #14	-	-	-	-	-
Well #15	1	**0.015**	0.52	3.22	394
Well #16	-	-	-	-	-
Well #16B	1	0.002	0.17	6.06	**752**
Well #17	1	0.003	0.17	**13.1**	**660**
Well #18	1	0.006	0.18	4.88	**531**
Well #19	1	0.005	0.18	4.45	474
Well #20	1	**0.015**	1.2	4.7	330
Well #21	1	<0.002	0.13	9.34	**1450**
Well #22	1	0.0031	BDL	**10**	**890**
Well #23	1	0.003	0.1	8.67	**824**
Well #24	1	0.0025	<0.4	6.9	**780**
Well #25	1	0.0039	BDL	**10**	**1100**
Well #26	-	-	-	-	-
Well #28	-	-	-	-	-

Notes: NA – Not Applicable
BDL – Below Detection Limit
Red text signifies values are above the MCL or secondary standard.

4.3.2. Surface Water

The City monitors water quality in the surface water on a quarterly basis. Samples are taken from the SRP canal turnout (prior to the Crystal Gardens wetlands) and at the influent to the recharge basins (after water has passed through the wetlands. As shown in Table 4-5, the water sampled at both locations meets nearly all primary and secondary standards for drinking water. The only contaminant higher than the primary standard is nitrite, and the wetlands pretreatment removes it effectively. TDS is higher than the secondary standard, but because secondary standards are non-enforceable and because it is comparable to the TDS in the groundwater that is already being delivered to customers in the City, advanced treatment (i.e., treatment beyond what is typical for surface water sources) will likely not be needed.

All herbicides and pesticides measured (alachlor, atrazine, chlordane, dalapon, 2,4-dichlorophenoxyacetic acid, dinoseb, endrin, heptachlor, heptachlor epoxide, lindane, methoxychlor, pentachlorophenol, simazine, toxaphene, picloram, and 2,4,5-trichlorophenoxypropionic acid) were below detectable limits in all samples. As such, these data are not reported in Table 4-5.

4.3.3. Reclaimed Water

The City's WRF influent and effluent water quality data from April 2004 through July 2009 were reviewed and are summarized in Table 4-6. The WRF is effective for reducing ammonia, five-day biochemical oxygen demand (BOD_5), total suspended solids (TSS), and many other parameters of interest. The reclaimed water produced by the WRF consistently meets the guidelines for Class B+ reclaimed water. Class B+ water is suitable for irrigation of orchards, vineyards, golf courses, and restricted-access landscaping. It may also be used for dust control, construction activities, livestock watering, and street cleaning. Recharge of the Class B+ reclaimed water is in accordance with the City's APP and has been approved by ADEQ.

The City's Reclaimed Water System Master Plan (2005) notes that concentrations of some parameters not shown in the table above may limit direct reuse opportunities (e.g., chloride, TDS, sodium, and phosphorus). As recommended in the Reclaimed Water System Master Plan, these parameters should be monitored and their effect on turf irrigation assessed on a regular basis if implementing a direct reuse program.

Table 4-5.
Surface Water Quality (2004 through 2008)

Parameter	MCL for Drinking Water Systems	Secondary MCL for Drinking Water Systems	SRP Canal Turnout	Recharge Influent
Field Data				
pH (SU)	-	6.5-8.5	8.3	8.3
Specific Conductance	-	-	1011	1026
Temperature (°C)	-	-	16.9	15.1
Inorganic Compounds				
Alkalinity (mg/L)	-	-	156	143
Boron (mg/L)	-	-	0.27	0.26
Calcium (mg/L)	-	-	56	51
Chloride (mg/L)	-	250	196	204
Fluoride (mg/L)	4.0	2.0	0.37	0.36
Nitrate as N (mg/L)	10	-	2.4	2.3
Nitrite as N (mg/L)	1	-	**1.4**	0
Potassium (mg/L)	-	-	6.3	6.5
Sodium (mg/L)	-	-	123	133
Sulfate (mg/L)	-	250	86	97
Total Dissolved Solids (mg/L)	-	500	**632**	**633**
Trace Metals				
Antimony (mg/L)	0.006	-	BDL	BDL
Arsenic (mg/L)	0.010	-	0.006	0.006
Barium (mg/L)	2	-	0.074	0.080
Beryllium (mg/L)	0.004	-	BDL	BDL
Cadmium (mg/L)	0.005	-	0.0002	0.0002
Chromium (mg/L)	0.1	-	0.009	0.010
Copper (mg/L)**	1.3	-	0.013	BDL
Iron (mg/L)	-	-	1.35	0.41
Lead (mg/L)**	0.015	-	0.004	0.002
Magnesium (mg/L)	-	-	26.5	28.8
Manganese (mg/L)	-	-	0.06	0.05
Mercury (mg/L)	-	-	BDL	BDL
Nickel (mg/L)	-	-	0.02	BDL
Inorganic Compounds				
Selenium (mg/L)	0.05	-	0.002	0.003
Thallium (mg/L)	0.002	-	BDL	BDL
Silver (mg/L)	-	0.10	BDL	BDL
Zinc (mg/L)	-	5	0.035	0.029

Note: Red text signifies values are above the MCL or secondary standard. Data represent the average of quarterly samples for a 5 year period (January 2004 to December 2008). Values for copper and lead represent "action levels" for distribution system samples.

Table 4-6.
Reclaimed Water Quality (2004 through 2009)

Parameter	No. Samples	50th Percentile	95th Percentile	Maximum	Class B+ Guidelines
pH	1677	7.24	7.51	7.98	NA
Chlorine Residual (mg/L)	1677	1.2	4	6	NA
E. Coli (CFU/100 mL)	799	12	300	1,400	NA
Fecal Coliforms (CFU/100 mL)	215	12	126	320	200/100 mL average; 800/100 mL single sample max
Turbidity (NTU)	1891	1.3	2.92	13.3	NA
Ammonia (mg/L)	639	1.3	7	73	NA
BOD_5 (mg/L)	240	8	20	73	30 mg/L 30-day average; 45 mg/L 7-day average
TSS (mg/L)	258	1.9	8.2	29	30 mg/L 30-day average; 45 mg/L 7-day average

5. Future Water Resource Planning Considerations

This chapter presents a review of additional water supplies that potentially may become available in the future, considerations for use of underground storage and recovery in-lieu of constructing water treatment plants, considerations with continued reliance on the CAGRD to demonstrate assured water supplies, potential impacts of a fully-implemented water conservation program, options for water reclamation and reuse, considerations for direct use of surface water, and water shortage/drought considerations for SRP and CAP water supplies.

5.1. Potential Additional Water Supplies

Several potential additional water supplies were evaluated in the 2002 Water Resource Master Plan. These potential additional water supplies included the following:

- SRP Allotments
- Groundwater from the Buckeye/St. Johns waterlogged areas
- Indian lease/settlement water
- Reclaimed wastewater

These supplies and their current and potential future roles in the City's water supply portfolio are discussed in the following sections, followed by discussion of other potential additional supplies:

- Reallocation of CAP M&I water
- Non-Indian agricultural CAP water
- Other CAP M&I supplies

5.1.1. SRP Allotments

The amount of SRP water that will be available for use within On-Project Areas will grow as agricultural On-Project Areas develop and the associated SRP entitlements are cut over to the City's account. According to SRP, as of August 17, 2009, the City has 4,901 acres cut over to the City account (SRP, August 2009). In the future, once all SRP eligible lands within the City are developed, the City should have 6,763 acres of land cut over to its account.

The amounts of various classes of SRP water that are available to the City member lands at any point in time are based upon the amount of water in storage and the amount of

water produced by the SRP watershed. Since 1931, SRP has generally been able to allocate 3 AFY/acre or more of stored (water stored in the SRP reservoir system) and developed water (groundwater from SRP wells) to its member lands. Only four times since 1931 (1940, 1947/1948, 1951, and 2003/2004) has it been necessary for SRP to reduce allocations to member lands to less than 3 AFY/acre (2 AFY/acre in all cases).

Based on the above, in "normal years," the City should be able to expect an allocation of up to 3 AFY/acre, or 14,700 AFY currently and 20,300 AFY at build-out of member lands. The actual SRP water delivered, however, cannot exceed actual member land water demands. Section 5.7 provides a discussion of non-normal or water shortage considerations for SRP and CAP water.

5.1.2. Groundwater from Buckeye/St. Johns Waterlogged Areas

The Buckeye/St. Johns waterlogged area occurs generally between Southern Avenue and the Estrella Mountains in Avondale. Groundwater from this portion of the City's service area is generally high in TDS (2,000 mg/L and higher) and in nitrates (greater than 5 mg/L). While this groundwater, under the current statutes, is exempt from water conservation and CAGRD accounting, it is generally expensive to treat the water to palatable levels and to manage the residual brine.

The CAWCD has embarked upon a preliminary feasibility study (Brackish Groundwater Treatment and Brine Disposal Feasibility Study) to determine potential costs associated with developing this groundwater as a regional water supply under the ADD Water program (Cullom, 2010). To date, however, the results of this work have not been published. As a regional program, the costs for accessing groundwater from the waterlogged area may be less than what the City would expend by itself. Since the ADD Water program is in its early stages, however, the feasibility of accessing this groundwater cannot be determined currently. The ongoing ADD Water work and discussions regarding the legal ramifications, potential treatment and use of the groundwater, and disposing of treatment by-products should eventually define the framework around which groundwater from the waterlogged areas can be accessed by the City and others.

5.1.3. Indian Lease/Settlement Water

The City participated in the negotiations for settling the water rights claims of the White Mountain Apache Tribe and is a party to the settlement. The City will be leasing 882 AFY of CAP water allocated to the tribe pursuant to the settlement. The lease water may be delivered to the City for underground storage at the CAWCD regional recharge facilities where the City has permits to lease storage capacity. The recharged water would then accrue as long-term storage credits for later recovery by the City from wells within its service area, or be used for annual storage and recovery. The City has been monitoring the progress of the White Mountain Apache Tribe settlement legislation and

currently anticipates that the settlement water will be available for lease on or before 2020.

Some of the other Arizona Indian tribes that have previously settled water rights claims include the Fort McDowell Indian Community, the Salt River-Pima Maricopa Indian Community, the San Carlos Apache Tribe, the Gila River Indian Community, the Tohono O'odham Tribe, and the Ak-Chin Indian Community. In most cases, leases from these tribes have been secured by parties to the settlements. Some of the tribes have additional supplies they could lease pursuant to language in their respective settlements. Based upon recent contacts, however, none of these tribes appear to have an interest in offering long-term leases of 50 years or more (ADWR, 2009).

5.1.4. Reclaimed Water

Other than SRP allotments, reclaimed water is possibly the only other supply of water that will increase as the City develops and grows. As previous City water supply planning efforts have stated, "reclaimed water is such a valuable water resource that it ALL should be reused or recharged" (RBF, 2002). Reclaimed water offers many valuable benefits, including that it is relatively drought proof, it can be treated to levels allowing a multitude of reuses, and use of reclaimed water for any demands that do not require potable water will free up the City's potable water supply for other domestic uses. Section 5.5 provides an overview of the City's efforts to plan for and implement its water reclamation and reuse program. Section 5.8 provides a description of how reclaimed water availability will be projected and added to the City's overall future water supplies.

5.1.5. Reallocation of CAP Municipal and Industrial Water

In the past, there have been times when the initial allocations of CAP M&I water have been changed based on various criteria and methods and become available for reallocation. ADWR staff was contacted to determine if any unallocated CAP M&I water was currently available for reallocation. ADWR indicated that there is no unallocated CAP M&I water available for reallocation at this time (ADWR, 2009)

5.1.6. Non-Indian Agricultural CAP Water

The Arizona Water Rights Settlement Act identified approximately 60,000 to 90,000 AFY of Non-Indian Agricultural (NIA) priority water for reallocation. ADWR staff was also contacted to determine the status of potential reallocation of the NIA priority water. According to ADWR staff, "This reallocation process will be very competitive; a number of municipal water providers have already expressed an interest in acquiring some of this water. ADWR must initiate a public process for the development of criteria for the pending NIA water reallocation, but recent budget cuts (and pending future cuts) have impacted its ability to begin this process. There have been a number of letters of interest including one from Northern Arizona. Process and criteria will have to be determined specifically for this reallocation, although need and ability to put the water to use in the

near term have always been part of allocation recommendations from the department" (ADWR, 2009).

If the City wishes to be considered for participation in the reallocation process, it should submit a letter of interest in acquiring a portion of this supply. If the City ultimately determines that this water is not needed, it can withdraw from the process at any time.

5.1.7. Other CAP M&I Supplies

Although none are known at this time, there have been existing CAP subcontractors who have been willing to sell all or part of their CAP subcontracts in the past. These were typically interests that did not have to acquire Designations of Assured Water Supply or Certificates of Assured Water Supply, such as industrial users. There would be a significant amount of competition for this water, however, including from the CAGRD who is aggressively pursuing any available water supplies. Acquisition of M&I subcontracts would require payment of all capital repayment obligations from the date of inception of the contract to the original subcontractor, plus adjustments for inflation, and administrative costs.

If the City wishes to be considered for any future CAP M&I supplies that become available, it should submit a letter of interest to ADWR and CAWCD expressing a desire to acquire any CAP M&I subcontracts that may be offered for sale. While the chances for success are unknown, the City should at least have its interest in additional CAP water on record. While it may be demonstrated that this water may not be needed in the future, any additional CAP water the City could acquire could provide a hedge against future water shortages and/or unplanned development (e.g., development south of the Estrella Mountains).

5.1.8. Access to Excess

As a result of increased demand for excess CAP water, the CAWCD has established new policies regarding the ordering and use of excess CAP water. This directly affects the City as it relies on excess CAP water to build its underground water storage balance and to supplement SRP surface water supplies during years with reduced storage and runoff. Although it is not likely, the consequences of this policy may be the reduction of excess water availability to the City.

Excess water has been placed into categories, or pools, based upon the type of use and user. The new policy essentially places municipal water users into the third of four pools of water. The first pool is known as the agricultural settlement pool. This pool of water must be satisfied, or filled, first based upon negotiated settlements; the policy currently adopted becomes effective in 2010 and remains in effect through 2014. After the agricultural settlement pool is filled, remaining excess water is available as follows:

- Arizona Water Banking Authority (AWBA) and CAGRD Replenishment Reserve Pool – 175,000 AF.
- CAGRD annual replenishment pool – 35,000 AF.
- Water not used by the AWBA or CAGRD in either of their pools is split between the Municipal Pool and the Industrial and Other Pool.
- Municipal Pool – 90 percent of water historically used by each entity, with the remaining 10 percent of historic orders distributed equally among all requestors. This will gradually shift to equal weighting by 2014.
- Industrial and Other Pool – This is broken into two tiers: industrial and remarketer. The industrial tier orders will be filled first and will be based on a three year rolling average of actual water deliveries for each entity. There are exceptions for small users (less than 1,000 AF) as long as their order is not greater than the previous three years. Water remaining is then available to the remarketer tier.

5.1.9. ADD Water

The Stakeholder Working Group is a group of more than 70 self-selected participants with an interest or stake in the outcome of the Acquisition, Development, and Delivery (ADD) Water process. Their purpose is to develop a range of distinct alternatives for the sharing and paying for the additional water needed to support current and future population in the three-county area that includes Maricopa, Pinal, and Pima counties. These alternatives will be compared and evaluated through the decision process. Water supplies that are being investigated include brackish groundwater from the southwest Valley area, the Lower Colorado River area, and/or desalinated seawater, perhaps from as far away as Mexico. The City has participated in this process since its inception and also is represented, in part, through its membership in the Arizona Municipal Water Users Association.

5.1.10. Outlook for Additional Future Water Supplies

Long-term renewable water supplies currently available to the region (CAP, SRP, etc.) have essentially been fully allocated. Other than NIA priority water, there are no more large blocks of readily available renewable supplies that the City can pursue to fill additional needs for growth beyond the scope of this project. The next large blocks of water supply for the region are believed to be brackish groundwater from the southwest valley area, the Lower Colorado River area, and/or desalinated seawater, perhaps from as far away as Mexico. Both supplies will require large-scale and complex agreements and regional efforts to allow cities like Avondale to gain access to the new supplies. The permitting and institutional processes to develop new additional water supplies could be too challenging, lengthy, and expensive for a single entity (like Avondale) to achieve on its own. Likely, a regional water agency (such as the CAWCD, Bureau of Reclamation, etc.) will implement the potential new supplies with the coordination, participation, and for the benefit of, communities in the region.

5.2. Underground Storage and Recovery

Current and potential future groundwater recharge capabilities must be factored into any water supply alternative that the City considers. The City currently relies on underground storage and recovery as the mechanism for using its renewable SRP and CAP water supplies. In late 2009, the City started using underground storage and recovery to manage its valuable reclaimed water resource.

5.2.1. Available Storage Capacity

Section 4 presented a summary of the recharge facilities that the City can currently use:

- The City owns the Avondale Recharge Facility which has a permitted capacity of 15,000 AFY. The Avondale Recharge Facility can be used to recharge SRP water, CAP water via the CSIF and the SRP canal system, and reclaimed water.
- The City has purchased 10 percent of the capacity in the SRP NAUSP facility. According SRP, the current permitted capacity of this facility is 50,000 AFY and is expected to be increased to the ultimate 75,000 AFY in 2010. As the facility is started up, SRP projects that the actual recharge capacity will increase from the current 25,000 AFY to 50,000 AFY in 2010, and to 75,000 AFY in 2011and beyond. Based on SRP's estimates, the City could have additional recharge capacity at the NAUSP of 2,500 AFY currently, building to 5,000 AFY in 2010 and to 7,500 AFY in 2011 and beyond. The NAUSP can be used to recharge the City's SRP and CAP entitlements.
- The City is permitted to lease recharge capacity in two CAWCD regional recharge facilities along the CAP Canal: up to 20,000 AFY in the Hieroglyphic Mountains facility and up to 40,000 AFY in the Agua Fria facility. The CAWCD takes recharge orders annually and could recharge in either of these facilities. Because of their physical locations, the CAWCD facilities will likely recharge the City's CAP allocations and other excess water delivered by the CAP system.

As all of the recharge facilities employ surface recharge basins (as opposed to vadose zone or injection wells), use of these facilities provides a relatively inexpensive method of diverting surface water from the SRP and CAP delivery systems for treatment and use. Essentially, the groundwater system operates both to equalize water deliveries with water production and distribution, and to "treat" the water to potable standards. This will be an added benefit once the City begins storing its reclaimed water supplies at its facility. Currently, recharge and recovery is the only way to convert reclaimed water to potable water in Arizona.

5.2.2. Groundwater Quality Considerations

One of the key disadvantages to using underground storage and recovery in this manner is that water quality within the groundwater system can be a limiting factor. This is especially true near the south-central portion of the study area where TDS and nitrates appear to be significantly greater than in the north. Additional concerns are associated

with the Phoenix/Goodyear Airport North Superfund Site in the northwestern portion of the service area. Potential migration of the contaminant plume from the Superfund site may impact and/or limit well siting and well operations in that portion of the service area.

5.2.3. Storage Capacity Considerations

As reclaimed water production increases, the City will have to continue use of the CAWCD facilities and begin to shift delivery of its SRP water to the NAUSP. Fortunately for the City, capacity is available at these other facilities as discussed above. There are, however, certain concerns that should be noted. The NAUSP is a fairly new facility. Initial results have shown lower than expected recharge capabilities. Although SRP is working diligently to rectify the recharge performance, the projected recharge performance is only SRP's best estimate at this time. Although substantial recharge capacity does exist at the CAWCD facilities, there is no long-term guarantee of recharge capacity for any one entity at these facilities. The CAWCD will only confirm recharge orders on an annual basis which may become problematic if competition for recharge capacity from other cities, the Arizona Water Banking Authority (AWBA), and the CAGRD, among others intensifies.

The current Avondale Recharge Facility is limited in capacity to 15,000 AFY. However, it may be possible to enhance recharge performance, and maybe even increase the recharge capacity at the facility if additional water production/recovery wells are located within the area of hydrologic impact of the storage facility. This would depend on whether the limiting subsurface hydrology is associated with the aquifer or the presence of perching layers in the unsaturated zone above the aquifer.

5.2.4. Potential Future ADWR Assured Water Supply Policies

According to the director of the Phoenix Active Management Area, the trend towards localized groundwater overdrafts is becoming a concern and may be addressed in the Fourth Management Plan for the AMA (Miller, 2010). This concern may impact the next time the City needs to apply for a Modification of Designation of Assured Water Supply. A primary concern of the ADWR is that water providers are storing large amounts of water in portions of the AMA where they cannot physically withdraw and use the stored water. This can create issues for the storer as well as users in the area where the water is being stored. The issues being created as providers are remotely recharging are as follows:

- Within the area of impact of a water provider (areas from which the water provider's wells extract water, or are likely to extract water in the future), the amount of water physically in storage may not equal the amount of water that the water provider may have legal access to extract.
- ADWR does not focus on water quality issues; however, there is recognition in the statutes and by ADWR that groundwater that is physically available to the provider

may experience significant water quality changes that could make the groundwater that is physically available expensive to use, to the point that the water provider no longer has the financial capability to use the groundwater (one of the requirements to obtain an AWS Designation).

Because of these concerns, ADWR is of the opinion that water providers located in areas where there may be adequate amounts of groundwater physically in storage, but the provider does not have "legal access" to the physically available groundwater, may need to exchange CAP water (if they have allocations) with the storer of the water (if they have direct physical access to the CAP water). If this is not viable, it may be possible that in the next round of modifications of designations, water providers that have adequate amounts of water legally available may be denied new designations because water may not be physically available to them.

If this policy becomes reality, there may be extra incentive to attempt to increase the amount of water that is stored within the City's service area, to the extent physically possible. However, if the ADWR asserts that there is inadequate capacity within the City's service area to store its reclaimed and/or CAP water, the City should insist that under such a determination, the water that IS physically available within the service area is also groundwater and stored water legally entitled to the City, and not to any other groundwater users or water stored by other users. In other words, the City's capacity to store in its service area should not be reduced on the basis of other water users' legal entitlements.

This is a complicated issue that ADWR is currently contemplating and it could change depending on many factors. The City needs to track the issue and potential new ADWR policies and needs to be a significantly-involved stakeholder to preserve its best chances for future Designations.

5.3. Central Arizona Groundwater Replenishment District

5.3.1. City of Avondale Membership

The City has obtained membership in the CAGRD as a way to achieve and maintain compliance with the requirements for obtaining a Designation of AWS. Although it is not a "source" of water in the true sense, membership does allow the City to access and use legally defined groundwater, as long as the groundwater is otherwise deemed to be "physically available" by the ADWR.

CAGRD assesses the City a replenishment fee if the City uses groundwater from its well system, and cannot, or elects to not account for the pumped groundwater as recovered water from its annual and/or long-term storage account. Since the City currently relies exclusively on its wells for its water supply, the City can elect to count up to 100 percent of its pumped water as groundwater. Alternatively, the City can elect to count up to 100 percent of its pumped water as recovered SRP and/or CAP water, and in 2010, reclaimed

water. This is a more economically attractive option as the cost of replenishment in the Phoenix AMA is reported to be $290/AF in 2010 and $318/AF in 2011. Future advisory rates (not yet approved by the CAGRD board) for the Phoenix AMA are projected at $346/AF, $358/AF, $367/AF, and $376/AF for each successive year.

Membership in the CAGRD is currently an option of choice by the City even though it can demonstrate that it has secured at least 100 years worth of renewable (legally defined as non-groundwater) supply for existing and future water demands. Because the City can meet future demands in other ways and because of the cost implications, CAGRD will not be shown as a supply of water in the Water Resource Master Plan update (Sections 5.8 and 7) when comparing the City's long-term water demands and supplies.

5.3.2. Potential Direct Delivery Memberships

The AWS provisions and the CAGRD statutes allows CAGRD, in very specific instances, to enter into contracts for direct delivery of specific water supplies to member entities. The direct deliveries are authorized only if they are made in lieu of pumping or replenishment. The CAGRD has arranged for a "direct delivery membership" in one instance. The contract was executed in November of 2001 between the CAWCD and the City of Scottsdale. Scottsdale was in the process of securing property in the Harquahala Valley for the purposes of acquiring the water rights associated with the property, and wanted to use this water pursuant to a CAGRD direct delivery contract. The agreement requires the purchase (Harquahala), or an alternate long-term supply purchase, be completed.

The agreement authorizes CAWCD to deliver up to 3,460 AFY of water (replenishment water) to the City for storage at the City's underground storage facility (the contract replenishment facility), and/or for direct delivery to customers served by wells (annual storage and recovery). Scottsdale bears all costs (capital, operations, maintenance, and replacement) associated with the required CAP turnout, conveyance system, and storage facility. The CAWCD has the option of using excess CAP water to meet the delivery obligations under the agreement, and will use the City's long-term water supply (Harquahala) if there is insufficient CAP excess water. The agreement also provides Scottsdale the option to purchase a total of 17,300 AF of long-term storage credits from the CAWCD. The agreement states that CAWCD shall set the tax (cost) for the water. The tax is 50 percent of the Phoenix AMA Replenishment Assessment for the current year and for future years, including the advisory rates.

If this opportunity does exist, it may be an option for securing a water supply for the planning area south of the Estrella Mountains, but would likely require the City to construct an additional underground storage facility, and a means to deliver water to the facility. In addition, the City would likely need to acquire/purchase a long-term water supply that would be dedicated to satisfying the demands associated with the agreement.

For purposes of expanding the City's water supply, this may be a potentially viable alternative water supply if the CAWCD/CAGRD is willing and able to enter into similar agreements.

The CAGRD was contacted to determine if the direct delivery opportunity remains available to others and under what terms. CAGRD indicated that a direct delivery contract is not an option for Avondale based upon the statutes that currently govern this specific program (Fletcher, 2010).

5.4. Water Conservation Program

Section 2 provided a summary of the City's water conservation program. The universe of water conservation programs is extensive and generalizing the potential impacts of a fully implemented program is, therefore, difficult. During the 1990s, the American Water Works Association surveyed 1,000 public water systems that served an estimated 175 million people and implemented some form of water efficiency or conservation program. Major types of programs involved many of the elements within the City's current program. The five major reasons cited for implementing water conservation programs included water shortage (32 percent of the utilities), systems operations or capital cost savings (17 percent) regulatory requirements (14 percent), public interest group pressure (4 percent), and declining groundwater table (3 percent). The following general short and long-term water use reductions were reported by the survey respondents (AWWA, 1996):

- Public information programs: 1 to 2 percent short-term
- Water conservation devices (low flow showers, etc.): 2 to 9 percent short-term
- Water rate increases/modifications: 1 to 20 percent short term, 2 to 20 percent long-term
- Water restrictions: 5 to 30 percent short-term, 2 to 30 percent long-term
- Combined reductions: 12 to 25 percent

Although the savings due to a fully-implemented water conservation program could be significant, this Water Resource Master Plan update will not consider water conservation as an additional supply of water. Historically, water planners have considered water conservation equivalent to an additional source of water that could be used to support new growth. However, recent trends show a movement away from that practice. Examples of reasons cited in the literature are that complacency is the biggest source of resistance to conservation: people are content with their lifestyles and water bills. Also, allocating conserved water to growth may compromise a water provider's ability to meet customer demand during shortages. The result would be "demand hardening" whereby a greater percentage of a customer's usage is nondiscretionary. With the buffer allocated to growth, both longstanding and new customers would need to endure lengthier and deeper water-use reduction mandates.

5.5. Water Reclamation and Reuse

5.5.1. Previous Water Reuse Planning

The City's 2002 Water Resources Master Plan included a discussion of potential water reuse and recommended a reclaimed water plan. At that time, it was projected that the City could produce 6,700 AFY (6 mgd) of reclaimed water, increasing to a little over 18,100 AFY (16 mgd) by 2040. The plan rightly indicated that "reclaimed water is such a valuable water resource that it ALL should be reused or recharged." Based on an analysis of possible end uses (direct use, water exchanges, and recharge), it was recommended that the reclaimed water be recharged at the Avondale Recharge Facility and later extracted using recovery wells. The recharge facility would have to be expanded and its recharge permits would have to be modified to permit recharge of reclaimed water. In addition, a pump station and pipeline would have to be constructed to convey reclaimed water from the WRF to the recharge facility. It was noted that the previous practice of discharging to the Agua Fria River had created a wetlands habitat downstream and that some discharge to the river might have to be maintained in the future to maintain the habitat.

The Reclaimed Water System Master Plan was developed for the City in 2005. Similar to the 2002 effort, this master plan indicated that it will be necessary for the City to use its valuable reclaimed water resource over the long term to meet a significant portion of its water demands. The master plan evaluated six reclaimed water distribution system alternatives for delivering reclaimed water to the Avondale Recharge Facility and to major turf irrigators within the City (schools, parks, homeowner association common areas, and highway/median landscape) and other private turf irrigators (golf courses, PIR). The objective of the plan was to identify all potential reclaimed water users and issues associated with developing and implementing a renewable supply of reclaimed water to meet the turf irrigation needs. The updated reclaimed water projections for the master plan were 5,400 AFY (4.8 mgd) in 2005 increasing to 14,500 AFY (12.9 mgd) in 2030. The master plan concluded that without some other political, legislative, or socioeconomic driver, recharging all of the City's Class B+ reclaimed water to acquire groundwater recharge credits and reusing a portion for golf course irrigation is the most cost-effective approach. It was noted, however, that factors such as public perception regarding the need for aggressive reuse, state legislative action requiring more reuse, etc. in the future may lend more political support towards implementing an expanded Class A+, high pressure reclaimed water distribution system even though it is not the most cost-effective approach.

The 2005 reclaimed water system master plan recommended the following implementation plan:

- 2005 – 2007: Construct a low pressure pump station and 2-million gallon storage tank at the water reclamation facility and a 24-inch pipeline from the pump station to

the Avondale Recharge Facility. Provide connections for the Coldwater Springs Golf Course and the City's Friendship Park and serve reclaimed water to the golf course if an acceptable agreement can be worked out.

- 2007 – 2010: Add an additional low-pressure pump as required for increased reclaimed water flows and serve reclaimed water to the Coldwater Springs Golf Course if an acceptable agreement can be worked out.
- 2015 – 2020: Add an additional low-pressure pump as required for increased reclaimed water flows.

If the City decides on its own, or is required to by public and/or legislative pressure, then the City would have to upgrade its water reclamation facility to produce Class A+ effluent, install high-pressure pumps at the pump station, and extend the reclaimed water distribution system to serve additional customers where it is cost-effective and/or politically desirable to do so. Pursuant to the recommendations above, the City has accomplished the following with respect to its reclaimed water resource:

- Although the wetlands habitat issue has not been formally resolved, the City has indicated that, for the time being, it would continue to discharge 1,120 AFY (1 mgd) of reclaimed water to the Agua Fria River.
- The Avondale Recharge Facility has been re-rated and permitted to an ultimate capacity of 15,000 AFY. The City has also permitted all existing groundwater production wells as recovery wells.
- The City has constructed a low pressure pump station at the reclamation facility and a pipeline to the Avondale Recharge Facility. The pump station and pipeline went into service in December 2009.
- To date, no agreement has been implemented with the Coldwater Golf Course for reclaimed water service. City staff indicates that since the golf course has its own SRP water supply, it is unlikely that an agreement can be implemented in the foreseeable future.
- The City would like to evaluate options for modifying the well that supplies irrigation water to Friendship Park (Well #16B) for potable service. If this is feasible, then the City may provide reclaimed water to the park for irrigation and lakes. However, since the park has unrestricted access, this would require the City to install filters at the reclamation facility to produce Class A+ reclaimed water.

5.5.2. Water Reuse Considerations for Water Resource Master Plan

Based on the review above, the Water Resource Master Plan update will incorporate the following water reuse assumptions:

- The City will continue to discharge 1,120 AFY (1 mgd) of reclaimed water to the Agua Fria River.

- If it is feasible to modify Well #16B for potable service, the Friendship Park irrigation and lake demands will be supplied initially with potable water, then with reclaimed water when it is feasible to do so.
- The remainder of the reclaimed water will be recharged at the Avondale Recharge Facility and groundwater credits will be recovered with City production (recovery) wells. This means that as reclaimed water production increases, the City will have to recharge its surface water supplies at other locations.

5.5.3. Reclaimed Water Quality Considerations

The 2005 reclaimed water system master plan also investigated additional reclaimed water quality considerations. First, the master plan investigated the effects of reclaimed water quality (namely salinity, sodium, chloride, and phosphorous) on turf irrigation. The master plan found that the City's reclaimed water is generally higher in some of the key constituents compared to groundwater and might present some problems for sensitive turf-grass varieties. However, reclaimed water is lower in every key constituent, with the exception of sodium, than SRP assessment water and is therefore more suitable for turf irrigation. The master plan indicated that continuous monitoring of the key constituents in reclaimed water and their potential irrigation impacts can diminish the impact of the higher constituent levels on selected turf grasses.

The 2005 reclaimed water system master plan also investigated several issues related to the safety of potable groundwater supplies due to the recharge of reclaimed water in the vicinity of domestic production wells. Some of the key conclusions reached by this effort include the following:

- The City's Class B+ reclaimed water is of sufficient quality to meet State aquifer water quality standards at the Recharge Facility, with the exception of fecal coliforms. Given the well documented ability of soil aquifer treatment systems to remove fecal coliforms, however, it was believed that the City would comply with the aquifer water quality standards by selecting new points of compliance that are ideally located 300 to 400 feet away from the recharge basins.
- A preliminary estimate of travel time between the recharge basins and the nearest production well, Well 12 at 1,500 feet away, is approximately two to three years.
- The disinfection of either Class B+ or Class A+ reclaimed water using chlorine would not produce trihalomethanes of sufficient concentrations to violate the aquifer water quality standards, and the low chlorine dosage rates (2.5 mg/L) needed to achieve non-detect levels of total coliforms would not require dechlorination of reclaimed water prior to recharge.
- The currently unregulated contaminants such as pharmaceuticals and personal care products (PPCPs) and endocrine disrupting compounds (EDCs) may be attenuated during tertiary treatment and soil aquifer treatment. However, there is a strong likelihood that some PPCP and EDC constituents will migrate from the recharge basins to down gradient production wells. PPCP and EDC contamination risk may be

minimized by providing additional treatment or by increasing the separation distance between recharge facilities and production wells.

- In the event that the State adopts portions of California's Title 22 regulations, it can be expected that the City will be required to produce Class A+ reclaimed water prior to recharge. Additionally, the regulations would require routine sampling for PPCPs and EDCs, although MCLs for these constituents have not yet been set.

5.6. Direct Use of Surface Water Supplies

The City wishes to explore the potential to treat its SRP entitlements and CAP allotments in a water treatment plant and use the water directly, rather than first recharging it. SRP and CAP waters are delivered through the SRP system of canals and irrigation laterals, and could, therefore, be comprised of varying mixtures of surface water and groundwater at any time. Even if the water is all groundwater, if it flowed in the open canal with any trace of surface water, the regulatory requirements for surface water would apply to the delivered water. That is, the water would fall within the USEPA category of groundwater under the direct influence of surface water, which (from a treatment perspective) is surface water. For this reason, the potential water treatment plant (WTP) is referred to as a surface WTP herein.

5.6.1. Previous Surface Water Treatment Planning

The City has been considering and studying how to best use its SRP and CAP water for several years:

- The 2002 Water Resources Master Plan conducted a cursory evaluation and concluded that because of the water quality fluctuations and the high percentage of tail water and groundwater that can be present in the canals near Avondale, a surface WTP would need some form of nitrate removal in addition to the conventional surface water treatment. Due to concerns with brine disposal from the nitrate treatment (reverse osmosis), surface water treatment was not recommended.
- The 2005 Wastewater Collection System Master Plan & Utility Systems Evaluation did not specifically evaluate surface water treatment. However, the recommendations in the plan are all based on the fundamental assumption that the City will continue to use wells as its sole supply source. Constructing a WTP or participating in a regional treatment facility could change the infrastructure recommendations.
- The Surface Water Treatment: Opportunities and Analysis Study completed in 2007 took a more detailed look at alternatives for using the City's SRP and CAP water: constructing a City-owned surface WTP, partnering with neighboring facilities (e.g., the potential Maricopa Water District WTP, a City of Phoenix WTP, and the Arizona American WTP), and continuing to recharge and recover the water. The study concluded that partnering with neighboring facilities had a higher life cycle cost than the other alternatives and consequently recommended continuing recharge/recovery

while deferring the decision about constructing a City-owned surface WTP until more evaluations can be conducted.

The discussions below build upon the prior evaluations and present additional information related potentially to building a City-owned surface WTP.

5.6.2. Water Treatment Plant Considerations

There are several considerations to include when evaluating the potential for a surface WTP. In addition to the regulatory requirements for surface WTPs that were presented in the Section 2, WTP siting, impacts on SRP operations, and water quality must also be considered.

Water Treatment Plant Siting

The City has identified two potential locations for a surface WTP: near the Avondale Recharge Facility (McDowell Road east of the Agua Fria River) and a location west of 107th Avenue and north of Van Buren Street. The alternatives will have their own source water conveyance, point of entry (to the distribution system) infrastructure, and operational requirements.

SRP Operations

Because the intake for the WTP would be located within the SRP canal system, it is essential to coordinate any plans for a WTP with SRP. In recent discussions with SRP, several implementation issues were presented. The following key points were raised during the discussions and would need to be discussed with SRP and resolved prior to implementing a surface WTP in Avondale.

System Operations

SRP is concerned about anything that would require a change in their operations and the effect it has on system efficiency, system reliability, and cost. For example, one of the major concerns could be potential requirements for SRP to more closely manage water quality in the Grand Canal because of a downstream water treatment plant (the Grand Canal is currently designated for irrigation and livestock water uses, but not domestic use). While most concerns can be addressed with engineering design, the effect on operations needs to be considered.

Water Rights

- The water use and delivery agreements with SRP are in place to allow a surface water treatment concept. The current delivery point is at the Crystal Gardens Wetlands. The agreements would also cover any water exchanges that might have to occur (e.g., CAP water).

- The City's agreement to receive CAP water through SRP's delivery network expired in 2006. The City submitted a formal request for renewal to SRP in October 2009.

Water Quality Standards

- The Grand Canal water quality standards are currently set for irrigation and livestock uses. If a water treatment plant were to be added to the canal, the standard would have to be changed to allow domestic uses. Although it is not currently designated for domestic use, all discharges (wells and others) are treated as if the canal is designated for domestic use. The Western Canal and the Arizona Canal are already designated for domestic use.
- The Grand Canal is subject to significant variability in water quality due to well pumping, surface runoff, and various drains into the canal. The canal has many SRP wells upstream that could pump into it. At the lower reaches of the canal, the water can be 100 percent groundwater at times. Many of these wells have elevated nitrate levels. Water quality would need to be studied and carefully considered in the design of the WTP. Water quality modeling would also be needed to determine the correct combinations of wells to operate simultaneously.
- SRP encouraged the City to consider using the Arizona Canal water as a source water because it has less variable water quality than the Grand Canal and is already designated for domestic uses. This is the reason that Glendale's Oasis WTP was sited and designed to take its water from the Arizona rather than the Grand Canal.

Delivery to the City

- The canal capacity is sufficient to handle the anticipated flow to the WTP (10 to 15 mgd). The canal is likely sufficient to handle flows significantly higher (up to 100 mgd), but this should be confirmed with SRP.
- The current delivery method to the Crystal Gardens Wetlands is via irrigation laterals that branch out from the Grand Canal. A dedicated pipeline (rather than an open lateral) would be the preferred delivery method to the WTP as it reduces potential for degrading the water quality (e.g., from agricultural return flows that empty into many laterals). At its closest point, the Grand Canal is several miles from the City boundary. The end of the canal is located near the intersection of 99th Avenue and Bethany Home Road.

Emergency Storage and Backup Supply

- The Grand Canal typically has an annual dry-up from early January to early February so SRP can conduct maintenance. A secondary source, such as a pipeline from another canal or groundwater wells, should be provided to back up the supply during canal dry-up and to increase system redundancy and robustness.
- On-site emergency raw water storage should be provided in the WTP design (up to 10 hours worth of storage) such that the City can always take delivery of ordered water, even if an emergency causes the canal or the plant to go offline. If storage is not

provided, the NAUSP delivery channel would need to be modified to take the water during an emergency.

In addition to these considerations, SRP has a guidance document for water treatment facilities within the SRP water system. The guidance document outlines requirements for planning and development, operations, design and construction, and facility maintenance (SRP, 1996).

As an alternative to constructing a City-owned WTP, SRP suggested that the City should consider partnering with a neighboring community or regional facility for treatment and delivery of SRP and/or CAP water to Avondale.

5.6.3. Water Quality

With respect to water quality and treatment, the City strives to have all contaminants less than 80 percent of the federal MCL at the point of compliance. The City also strives to provide water that meets the secondary standards with the exception of TDS, which has a non-enforceable secondary standard of 500 mg/L. The City's goal is to provide drinking water with TDS less than 700 mg/L; however, TDS up to 1,000 mg/L is acceptable. Although this is the current practice, there may be situations (emergencies, water is needed for blending, etc.) where water with a TDS higher than 1,000 mg/L will be served.

The City provided water quality data from the Crystal Gardens Wetlands influent and the influent to the recharge basins which were sampled quarterly from 2004 to 2008 (Section 4.3). Nearly all compounds were below the federal primary and secondary MCLs except for a few selected nitrite samples and TDS. Additional data provided by SRP at the tail of the Grand Canal (near the intersection of 99th Avenue and Bethany Home Road) showed similar water quality trends as the data provided by the City except for nitrate and nitrite, both of which were higher than the City's data and higher than the MCL. TDS is historically higher than the secondary standard of 500 mg/L; however, on average it is less than 700 mg/L, which is less than the City's goal.

5.6.4. Surface Water Treatment Assumptions

Based on the review above, the Water Resource Master Plan update will evaluate and incorporate the following surface water treatment assumptions:

- The location of the WTP will either be near the Avondale Recharge Facility or the location west of 107th Avenue and north of Van Buren Street.
- The source water for the WTP will be from the Grand Canal and will be conveyed to the surface WTP in a lateral. A dedicated pipeline constructed from the Arizona Canal to the surface WTP (24-inch, 12.5 miles) would cost approximately $24 million.

- The treatment process will include conventional treatment to reduce or remove turbidity, TOC, and microorganisms. If the Grand Canal is the water source, a side-stream RO process may have to be included to reduce nitrate during periods when groundwater contribution and nitrate are high in the canal water. Nitrate removal will likely not be needed if the Arizona Canal is the water source.

5.7. Water Shortage Considerations

One of the primary challenges in water supply planning is predicting the availability of water supply over an extended period of time, particularly the effects of climatic drought or extended periods of supply shortage. Nonetheless, water shortage considerations should be taken into account in two respects. First, the planned population growth, changes in land uses, and associated water demand projections should be compared against supply shortages that may occur during the planning period to determine if available water supplies can reasonably be expected to support the planned growth. Secondly, an assessment should be made to determine if an emergency reserve of water should be banked and/or access to alternative supplies be made to prepare for prolonged water shortages (i.e., firm the supplies to mitigate the effects of prolonged shortages). The following sections discuss water shortage considerations applicable to the City's available water supplies, concluding with an approach to identifying a reserve of water that the City should set aside for drought or water supply emergencies.

5.7.1. Groundwater

In terms of long range water planning, groundwater is typically considered a reliable supply during climatic drought. However, this supply must be carefully managed to avoid long-term overdraft, which can effectively remove the supply from consideration as a drought supply, or even a base supply, due to water quality degradation, land subsidence, and excessive costs to pump the water from greater depth. In extreme conditions, an aquifer can be dewatered. To maintain this supply as a form of "drought insurance," recharge/replenishment of the groundwater supply should be a fundamental principal of an effective water resources management program.

5.7.2. Reclaimed Water

Reclaimed water is also considered to be a highly reliable supply. It is not subject to climate-based drought, and it only has minor seasonal fluctuations in amount available. Reclaimed water also grows over time with increases in water demand. The amount of reclaimed water available in any given year will depend on the amount of wastewater generated.

5.7.3. Salt River Project Water

As indicated in Section 5.1.1 above, since 1931, SRP has generally been able to provide at least 3 AFY/acre of assessment water (surface water and groundwater), despite extreme variations in watershed flows from year to year. SRP manages its reservoir

system and extensive network of wells to maintain a consistent supply of water to its member lands. Only four times since 1931 (1940, 1947/1948, 1951, and 2003/2004) has it been necessary for SRP to reduce allocations to member lands to less than 3 AFY/acre (it has reduced allocations all four times to 2 AFY/acre). Based on this history, the summary of available future water supplies in Section 5.8 and the comparison of water demands and supplies in Section 7 will consider a "low supply" of SRP water as 2 AFY/acre and a "normal supply" as 3 AFY/acre.

5.7.4. Central Arizona Project Water

In the history of the CAP system, there has never been a shortage of CAP supply or reductions in allocations for Arizona communities. There are, however, circumstances that leave Arizona (and Avondale) vulnerable to shortages. As part of the authorization of the CAP, Arizona agreed to maintain the most junior status in priority relative to other lower basin states. This means that if there are insufficient supplies available to meet the combined allocations for California, Arizona, Nevada, and Mexico (the lower basin states), Arizona's annual allocation of 3 million AF would be cut first (along with Nevada and Mexico allocations). Within Arizona's annual allocation, the 1.5 million AF CAP component is the most junior and would bear 90 percent of Arizona's reduction in Colorado River supplies. In addition, according to historical flow records and analyses of 500 years of tree ring records, CAP has demonstrated that the flows of the early 1900s (upon which the CAP allocations were established) are likely high in comparison to the long-term averages; i.e., the Colorado River system is likely over-allocated.

The vulnerability to shortages has caused Arizona to seek solutions such as underground storage or "banking" of excess Colorado River supplies through the AWBA and by individual water providers. To date, the AWBA has stored more than 3 million AF for use during future CAP cutbacks. The total amount of long-term storage credits stored in the Phoenix AMA by the AWBA for CAP firming is a little over 1 million AF, which represents approximately 71 percent of the AWBA CAP Phoenix AMA firming goal of 1,566,000 AF. The AWBA projects that the CAP firming goal for the Phoenix AMA will be accomplished by 2018. This means that by 2018, the AWBA believes there would be enough water stored to replace all projected shortages through the next 100 years in the Phoenix AMA.

Notwithstanding the firming activities of the AWBA and others, it is prudent for the City to plan for some level of reduced CAP allocations. For the purposes of this Water Resource Master Plan update, a "low" supply represented by a 30 percent reduction in the City's CAP allocations will be evaluated.

5.7.5. Firming of SRP and CAP Water

The previous sections have indicated that the occurrence of reductions in water entitlements on both the SRP and CAP systems has been non-existent or minimal in

recent history. However, a 2005 Tree Ring Study, funded in part by SRP, found that there is a greater than 10 percent chance that extreme shortages in both the SRP and CAP systems simultaneously could occur in any single year (Hirschboeck, 2005).

The approach used to identify a recommended emergency supply of water that the City should provide included an assessment of the effects of various combinations of shortage occurring on the SRP and CAP systems at the same time. Based on the discussions in the previous sections, the following shortage levels were considered:

- SRP water allocations at 2 AFY/acre, 1.5 AFY/acre, 1 AFY/acre, and 0.7 AFY/acre. The supply allocations would consist of only water that is stored in the reservoir system and allocated to eligible members (stored water). The supply of 0.7 AFY/acre represents the lowest SRP stored water allocation of record since the allocations have been tracked by SRP.
- CAP water allocations at the full contract allocation and at 90, 80, and 70 percent of the full allocation. The reduced allocations would correspond to 10, 20, and 30 percent reductions, respectively. For purpose of the analysis, the White Mountain Apache Tribe Indian Settlement Water was also assumed to have reductions equal and simultaneous to CAP water, and this water was assumed to become available no sooner than 2020.

In addition to the low probability of water shortage conditions occurring on the SRP and CAP systems simultaneously, a conservative or worst case approach is used to identify a suggested emergency reserve of water based on the following assumptions:

- SRP water use is allowed only to satisfy the full demands on SRP member lands; i.e., there is no use of excess SRP water.
- Only entitlements to SRP stored water are considered, and other classes of SRP water such as normal flow are not considered.
- Potential demand reductions due to water conservation or implementation of the City's drought plan are not considered.
- Only annual storage and recovery of renewable supplies (SRP, CAP, and reclaimed water) are considered; i.e., no groundwater allowances or use of long-term storage credits are considered.

Appendix B contains the detailed evaluations of varying levels of shortage occurring on the SRP and CAP systems simultaneously. Table 5-1 summarizes the bottom line results of the drought/shortage evaluations. The table summarizes the combined supply balance on the SRP On-Project and Off-Project Areas due to the droughts/shortages occurring at each planning year through build-out of the study area (City planning area north of the Estrella Mountains). As expected, supply shortages generally occur for the combination of the most severe shortages and later in the study period. The analyses for 2010 and 2015 are for illustrative purposes only. Based on information cited in the body of this

report, there are no projections for reductions of SRP or CAP supplies to below normal allocations or less for this time period.

Table 5-1:
SRP and CAP Drought/Shortage Evaluation Summary

SRP Supply	CAP Supply[1]	Total Supply Balance (Deficit), AFY				
		2010	2015	2020	2030	2050
2 AFY/acre	Full Allocation	3,418	3,107	3,659	1,086	263
1.5 AFY/acre	Full Allocation	3,418	2,600	1,437	(1,649)	(2,485)
1 AFY/acre	Full Allocation	1,143	(118)	(1,503)	(5,030)	(5,866)
0.7 AFY/acre	Full Allocation	(354)	(1,749)	(3,267)	(7,059)	(7,895)
2 AFY/acre	Reduced to 90%	2,876	2,565	3,029	456	(367)
2 AFY/acre	Reduced to 80%	2,335	2,024	2,399	(174)	(997)
2 AFY/acre	Reduced to 70%	1,793	1,482	1,770	(803)	(1,626)
1.5 AFY/acre	Reduced to 90%	2,389	1,570	240	(2,845)	(3,681)
1.5 AFY/acre	Reduced to 80%	1,902	1,083	(326)	(3,412)	(4,248)
1.5 AFY/acre	Reduced to 70%	1,414	1,151	(893)	(3,979)	(4,815)
1 AFY/acre	Reduced to 90%	601	(660)	(2,133)	(5,660)	(6,496)
1 AFY/acre	Reduced to 80%	60	(1,201)	(2,763)	(6,290)	(7,126)
1 AFY/acre	Reduced to 70%	(482)	(1,743)	(3,392)	(6,919)	(7,755)
0.7 AFY/acre	Reduced to 90%	(896)	(2,290)	(3,897)	(7,689)	(8,525)
0.7 AFY/acre	Reduced to 80%	(1,437)	(2,832)	(4,527)	(8,319)	(9,155)
0.7 AFY/acre	Reduced to 70%	(1,979)	(3,373)	(5,156)	(8,948)	(9,784)

Note:
(1) Includes White Mountain Apache Tribe Lease Water.

With SRP supplies at 2 AFY/acre and the full CAP allocation, the City should have surplus water available to retain as long-term storage credits through build-out. On balance, the City has a favorable water supply portfolio that will provide surplus water in normal years, with a moderately increasing frequency of water supply shortages during below normal (1.5 AFY/acre) and dry (1.0 AFY/acre) years in the future as demand continues to increase. The addition of reclaimed water to the supply portfolio proves to be an excellent water management strategy and will moderate the effects of renewable water shortages while providing the City the ability to use excess water in the immediate years to build stored water credits.

Based on the findings of the tree ring study and predictions for drought/shortage to occur on both the SRP and CAP systems simultaneously and the knowledge that both systems have reservoir storage to buffer the shortages, it would be reasonably conservative to plan for a shortage on both systems that could adversely affect the availability of the respective water supplies ten times during the next 100 years. Considering the worst case

shortage conditions at build-out (SRP supply at 0.7 AFY/acre and 30 percent reductions in CAP allocations), the City could experience a need to withdraw up to 9,800 AF of stored water from its storage account. Thus, conservatively, the City should store, and maintain in storage, enough water to cover up to ten extreme shortage conditions over a 100 year period, at build-out demands, or a total of 98,000 AF of long-term storage credits.

5.8. Future Water Supplies

Section 3 provides a discussion of water supplies currently available to the City, including current SRP and CAP allocations and current groundwater allowance and stored water balances. The review above indicates that additional water supplies that the City can reasonably rely upon in the future include additional SRP entitlements, additional reclaimed water, and the White Mountain Apache Indian water lease.

Table 5-2 summarizes the water supplies that will be considered in evaluation of future water demand and supply balances. It should be noted that the water supplies included in Table 5-2 have specific and complex constraints (particularly SRP assessment water) regarding their use. The water supply amounts have been simplified to allow generalized demand/supply comparisons. The water supplies included in Table 5-2 are briefly described below:

- Groundwater Allowance is the City's groundwater allowance balance of 59,220.14 AF spread out over 100 years.
- Incidental Recharge is to be calculated as 4.43 percent of total annual water demands.
- Long-Term Storage Credits is the City's long-term storage balance 43,625.93 AF spread out over 100 years.
- CAP Incentive Recharge is the City's planned purchase of this water and included in the Capital Improvement Plan for fiscal years 2008 through 2012 of 5,000 AFY (total of 25,000 AF) spread out over 100 years.
- Peoria Effluent Credits are the credits that have been transferred from Peoria to Avondale in 2008 and 2009 (1,143.17 AF total) in exchange for Peoria's use of Avondale's capacity in the NAUSP facility. These credits are assumed to be spread out over 100 years.
- CAP Surface Water is the City's current CAP allocation. A high CAP allocation for normal years and a low CAP allocation for shortage conditions will be considered. Based on previous discussions, the low allocation is based on a 30 percent reduction in CAP allocations during shortage conditions.
- SRP Assessment Water is the City's entitlements to SRP water. Based on previous discussions, the low assessment is based on 2 AFY/acre and the normal assessment is based on 3 AFY/acre. The SRP cut over acres used in Table 5-2 are based on values provided in the August 2009 SRP Water Entitlement Report. The SRP Water

Entitlement Report cut over acres over time were straight lined between 2009 and 2030 (2030 is the estimated build-out for undeveloped On-Project areas based on the City's Estrella Foothills Specific Plan).

- Reclaimed Water is the reclaimed water to be produced from projected wastewater flows.
- WMAT Lease is the White Mountain Apache Tribe Indian Settlement Water that the City anticipates to start leasing on or before 2020. Similar to other CAP allocations, a high lease allotment for normal years and a low lease allotment for shortage conditions will be considered. Based on the above discussions, the low lease allotment is based on a 30 percent reduction during shortage conditions.

Table 5-2:
Future Water Supplies

Supply	2010		2015		2020		2030		2050	
	Low (AF)	Normal (AF)	Low (AF)	Normal (AF)	Low (AF)	Normal (AF)	Low (AF)	Normal (AF)	Low (AF)	Normal (AF)
Groundwater Allowance [1]	592		592		592		592		592	
Incidental Recharge[2]	641		764		950		1,257		1,310	
Long-Term Storage Credits [1]	436		436		436		436		436	
CAP Incentive Recharge[2]	250		250		250		250		250	
Peoria Effluent Credits [1]	11		11		11		11		11	
CAP Surface Water	3,791	5,416	3,791	5,416	3,791	5,416	3,791	5,416	3,791	5,416
SRP Assessment Water	9,980	14,970	10,870	16,305	11,760	17,640	13,526	20,289	13,526	20,289
Reclaimed Water	5,201		6,277		7,768		10,290		10,645	
WMAT Lease	0	0	0	0	617	882	617	882	617	882

Notes:
(1) City of Avondale Water Portfolio, December 2, 2009 (included in Appendix A).
(2) Water Resource Master Plan update Water Demand Projection Tool.

THIS PAGE INTENTIONALLY LEFT BLANK

6. Water Resource Projections

This section describes the development of water resource projections which includes water demands, wastewater flows, and reclaimed water availability, as reclaimed water is anticipated to be a critical component of the City's future water supplies. The description includes a review of previous projection methodologies, an overview of the current projection approach, a review of historical water use and wastewater flows, development of water demand and wastewater flow factors, and use of a GIS tool to project water resource demands.

6.1. Previous Water Planning

Several water planning reports previously completed for the City were reviewed to determine the methodologies and demand factors used to project future water resource demands. The following previous planning reports were reviewed:

- Water Resources Master Plan (RBF Consulting, 2002a)
- Water Infrastructure Master Plan (RBF Consulting, 2002b)
- Wastewater Collection System Master Plan & Utility Systems Evaluation (Carollo Engineers, 2005)
- Water System Model Update and Analysis (Carollo Engineers, 2009)

6.1.1. 2002 Water Resources and Water Infrastructure Master Plans

The 2002 master plans develop and compare both population-based and land use-based water demand projections. The study area for both efforts included the City's MPA north of the Estrella Mountains.

The population projections for build-out assumed maximum densities allowed for each General Plan land use classification, assuming that build-out would occur by 2040. The 2001 calculated combined residential and non-residential per capita consumption was determined to be approximately 188 gpcd. This demand rate averages the residential and non-residential demands over each resident. It was noted that the historical gpcd was increasing by approximately five percent per year, but that the increase was leveling off. The population-based demand projections were based on a combined per capita demand of 200 gpcd. In 2002, the population-based build-out water demand for the study area was estimated at 37,562 AFY for a projected population of 167,665 north of the Estrella Mountains. In addition, it was projected that there could be an additional demand of 9,857 AFY (44,000 people) in the MPA, south of the Estrella Mountains.

Land use-based water demand factors, in gallons per acre per day (gpad), were developed based on water production and consumption data. Table 6-1 presents a summary of the demand factors that were utilized in the 2002 master plans. The land use-based water demands for City build-out north of the Estrella Mountains was projected to be 37,000 AFY compared to the 37,562 AFY population-based projection.

Table 6-1:
Comparison of Previous Land Use Categories and Demand Factors

2002 Water Resources and Water Infrastructure Master Plans		2005 Wastewater Collection System Mater Plan & Utility Systems Evaluation			2009 Water System Model Update and Analysis	
Land Use	**Water Demand (gpad)**	**Land Use**	**Wastewater Loading (gpad)[1]**	**Water Demand (gpad)[2]**	**Land Use**	**Water Demand (gpad)[3]**
-	-	-	-	-	RLDR (0.2 du/ac)	74
LDR (2 du/ac)	1,000	LDR (< 2.5 du/ac)	211	341	LDR (1 du/ac)	368
MDR (4 du/ac)	2,000	MDR (2.5 - 8 du/ac)	834	1,348	MDR (3.75 du/ac)	1,378
-	-	Future MDR (4.5 du/ac)[4]	936	1,512	MHDR (4 du/ac)	1,470
HDR (10 du/ac)	5,000	HDR (> 8 du/ac)	1,689	2,729	HDR (8 du/ac)	2,940
-	-	-	-	-	MFR (12 du/ac)	4,410
Commercial	2,000	Commercial/Office	757	2,232	Commercial	1,850
Non-Residential[5]	1,000	Large Retail	757	2,232	Freeway Commercial	1,300
-	-	Industrial	698	1,152	Employment	1,000
-	-	-	-	-	Mixed Use	2,230
Turf[6]	4,000	School	174	1,152	Public Facilities	1,100
-	-	Park	-	2,304	Open Space - Irrigation	2,300
-	-	PIR[7]	979	979	-	-
-	-	Lake	-	-	-	-
-	-	Rivers and Desert	-	-	-	-

Notes:
(1) Based on 65 gpcd for residential land uses. Unit loads for certain areas were adjusted to better match metered flows.
(2) Based on 105 gpcd for residential land uses.
(3) Based on 3.5 residents/du (dwelling unit) and 105 gpcd for residential land uses.
(4) Undeveloped MDR or HDR, at average of 4.5 du/acre
(5) Includes all other non-residential other than Commercial.
(6) Assumed that each Open Space area would have 75 percent turf coverage.
(7) Phoenix International Raceway; based on 1.0 mgd or 2,370 gpad peak water demand, or 979 gpad average water demand.

Moving forward, both 2002 master plans used the population-based demand projections. The water infrastructure master plan distributed the projected populations and demands throughout the study area based on development progress information (estimated number of lots being built in subdivisions over time) provided by the City Planning Department. The development progress information was incorporated into MAG traffic analysis zone (TAZ) boundaries for spatial distribution.

6.1.2. 2005 Wastewater Collection System Master Plan & Utility Systems Evaluation

The study area for the 2005 wastewater and water master plans was also the City's MPA, north of the Estrella Mountains. This master planning effort used land use classifications from the City's 2002 General Plan to develop demand projections. A land use map was created by first assigning land uses for existing developed areas according to City zoning ordinance information. Ambiguous land use classifications in the zoning ordinance such as *planned area developments* were assigned to specific land use classifications according to information in the City's General Plan. Undeveloped area land uses were also assigned based on the General Plan.

Water demands and wastewater flows for the Avondale Auto Mall were handled individually based on water billing and wastewater flow monitoring data. Areas served by Liberty Water were not expected to be served by the City, and areas served by the Rigby Water Company were assumed to be connected to the City by 2010. The PIR was assumed to be connected to the City at build-out. To project development growth, estimated 2005 and 2010 developed area percentages were developed for each parcel within the City.

- **Wastewater Flows:** Unit wastewater loads, also shown in Table 6-1, were developed from mass balances using wastewater flow monitoring data. Unit wastewater loads for the PIR were estimated based on an estimated peak water demand of 1.0 mgd. Loading factors for certain wastewater drainage areas were adjusted to match their respective monitored wastewater flows. Appendix A presents a table and figure that illustrates how the wastewater flow factors were assigned. The wastewater infrastructure evaluations included an assumed 10 percent factor for infiltration and inflow. Wastewater flows (high weekend flows) at City build-out were projected to be 16,300 AFY (14.5 mgd) for a population of 161,633 north of the Estrella Mountains.
- **Water Demands:** Unit water demand factors, also summarized in Table 6-1, were derived from water production and water billing data and were adjusted to match estimated 2004 demands with actual production. Non-revenue water was conservatively assumed to be 10 percent for planning purposes. Water demands at City build-out were projected to be 34,300 AFY (30.7 mgd) for a population of 161,633 north of the Estrella Mountains.

6.1.3. 2009 Water System Model Update and Analysis

The 2009 Water System Model Update, which was completed prior to commencement of this current Water Resource Master Plan project, focused only on demand projections for the purpose of updating the City's water system model. The study area included only areas north of the Gila River because the City had no development plans south of the river, and the PIR had its own water supply. Water demands were based on land use classifications from the City's 2002 General Plan; however, minor modifications to the

General Plan land uses were made to more accurately show new and proposed developments. A pending South Avondale (between the Gila River and I-10 freeway) General Plan was acknowledged but was not used because it had not been finalized. The demand projections were based on assumed percentages of development in each land use polygon for interim planning periods and build-out.

Residential unit water demands were developed based on target densities for each land use classification, an average 3.5 people per dwelling unit, and an average of 105 gpcd. Non-residential unit water demands were developed from fiscal year 2008 customer billing data for the largest water users. Table 6-1 also summarizes the unit water demand factors that were utilized in the 2009 Water System Model Update. The *Mixed Use* demand factor was calculated as a weighted average of the individual land uses typically associated with *Mixed Use* in an average square mile. The 2009 Water System Model Update, which was completed prior to commencement of this current Water Resource Master Plan project, projected that water demands at City build-out (a build-out date was not estimated) were projected to be 22,600 AFY (20.2 mgd) for a population of 124,974 north of the Estrella Mountains.

The calculated water demand estimates for 2008 were compared with 2007 production records for calibration of demand factors because it was felt that the 2008 records were anomalous due to the current economic conditions (i.e., there had been a significant number of home foreclosures and businesses closing in the City).

6.2. Current Planning Approach

The approach used to develop water resource projections for this Water Resource Master Plan update differs in three ways from the previous water supply planning efforts:

- A new land use map was developed based on current information of existing land uses and future development planning.
- New unit water demand factors were developed based on those developed in the 2009 Water System Model Update and Analysis. New wastewater and reclaimed water factors were also developed based on the 2005 Wastewater Master Plan. These water, wastewater, and reclaimed water unit factors were adjusted to reflect recent demand and flow patterns observed.
- A GIS tool was developed to simultaneously project water demands, wastewater flows, and reclaimed water availability. Once loaded with the land use map and water resource unit demand factors, the tool quickly and easily assesses any alternative development scenario posed by the City. Land uses, land use densities, development timing, and other planning information for any planning unit or collection of planning units could be changed, resulting in updated water demands, wastewater flows, and reclaimed water available. The development and calibration of the GIS water resource projection tool is described in Appendix C.

6.3. Current Planning Framework

6.3.1. Land Use Classifications

The demand projections in this Water Resource Master Plan update are based on the land use classifications in the City's 2002 General Plan. Definitions for each land use category obtained from the General Plan are given below along with density ranges, in dwelling units per acre (du/acre), for each residential land use category.

- **Freeway Commercial (FRCO) -** Accommodates the more intense uses of the I-10 and Loop 101 corridors. It is intended that this category would allow flexibility for development by allowing regional retail, neighborhood retail, family entertainment, office, and employment uses.
- **Commercial (C) -** Provides for the daily needs of goods and services of the residents within the surrounding area. The types of uses allowed in this category include grocery stores, gas stations, neighborhood services, and offices. Preferred locations are major arterial intersections, although other locations may be deemed acceptable based on the merits of the project. In addition, services that provide shopping and basic services for the immediate area (i.e., "neighborhood commercial") may be allowed in any land use classification based upon the merits of the development proposal. Generally neighborhood commercial development would not be greater than five acres and would require adequate buffering to protect surrounding land uses.
- **Mixed Use (MU) -** Provides for a mix of high intensity uses with a retail commercial emphasis. This designation may include a maximum of 45 percent residential use. Mixed Use may include neighborhood and community retail, residential, hotel/motel, and employment.
- **Employment (E) -** Encourages uses that provide employment opportunities. The types of uses allowed in this category include general office and enclosed industrial uses, along with retail and commercial uses that support these primary employment uses.
- **Multi-Family Residential (MFR, 12+ du/acre, Target Density = 12 du/acre) -** The types of developments appropriate to this land use include apartment, condominium, patio home, and town-home development. Churches, parks, open spaces, and public facilities are permitted in this land use category.
- **High Density Residential (HDR, 8 -12 du/acre, Target Density = 8 du/acre) -** Can include town-home, condominium, patio home, and apartment developments. Churches, parks, open spaces, and public facilities are permitted in this land use category.
- **Medium High Density Residential (MHDR, 4 - 8 du/acre, Target Density = 4 du/acre) -** Can include single-family, attached and detached condominium, and patio homes, and townhome development. Churches, parks, open spaces, and public facilities are permitted in this land use category.

- **Medium Density Residential (MDR and MDRE, 2.5 - 4 du/acre, Target Density = 2.5 du/acre) -** Can include single-family attached and detached dwelling units. Churches, parks, open spaces, and public facilities are permitted in this land use category.
- **Low Density Residential (LDR, 1 - 2.5 du/acre, Target Density = 1 du/acre) -** Can include single-family detached dwelling units. Churches, parks, open spaces, and public facilities are permitted in this land use category.
- **Rural Low Density Residential (RLDR, 0 - 1 du/acre Target Density = None) -** Rural low density residential will not exceed a density of one single-family detached dwelling unit per acre. Churches, parks, open spaces, and public facilities are permitted in this land use category.
- **Open Space (OS) -** Open space is planned to set aside areas of active and passive recreation for Avondale residents and to preserve areas of critical natural habitat.
- **Public Facilities (PF) -** This land use includes a variety of public facilities to provide for the health, safety, and welfare of the City's residents. Types of uses found in this category include City government facilities, police and fire stations, schools, wastewater treatment facilities, well sites, substations, and other public facilities.

Since the last water supply planning effort, the City currently has developed two specific land use plans covering two areas of the City that will be incorporated into the current Water Resource Master Plan update: the 2008 City Center Plan and the 2009 DRAFT Estrella Foothills Specific Plan. These specific plans include other land use categories that are not included in the 2002 General Plan. To maintain consistency with the previous planning efforts, the use of specialized land use categories were kept to a minimum (developing demand factors for these special categories would also be difficult without specific, historical water demand data). Land use classifications in these specific plans were redesignated herein as follows:

- The Estrella Foothills Plan *Regional Commercial* and *Local Commercial* categories were changed to *Commercial*
- The Estrella Foothills Plan *Industrial* category was changed to *Employment*
- The Estrella Foothills Plan *Sports and Entertainment* category was changed to 50 percent *Employment* and 50 percent *Commercial*
- The Estrella Foothills Plan *Festival District*, *Village District*, and *River Walk District* categories were changed to *Mixed Use*
- Areas set aside for the development of State Route 801 in the Estrella Foothill Plan were classified as *Open Space*
- The City Center Plan *Employment Mixed Use* and *Gateway Employment* categories were changed to *Employment*
- The City Center Plan *Residential Mixed Use* and *Townhouse Residential* categories were changed to *Multi-Family Residential*

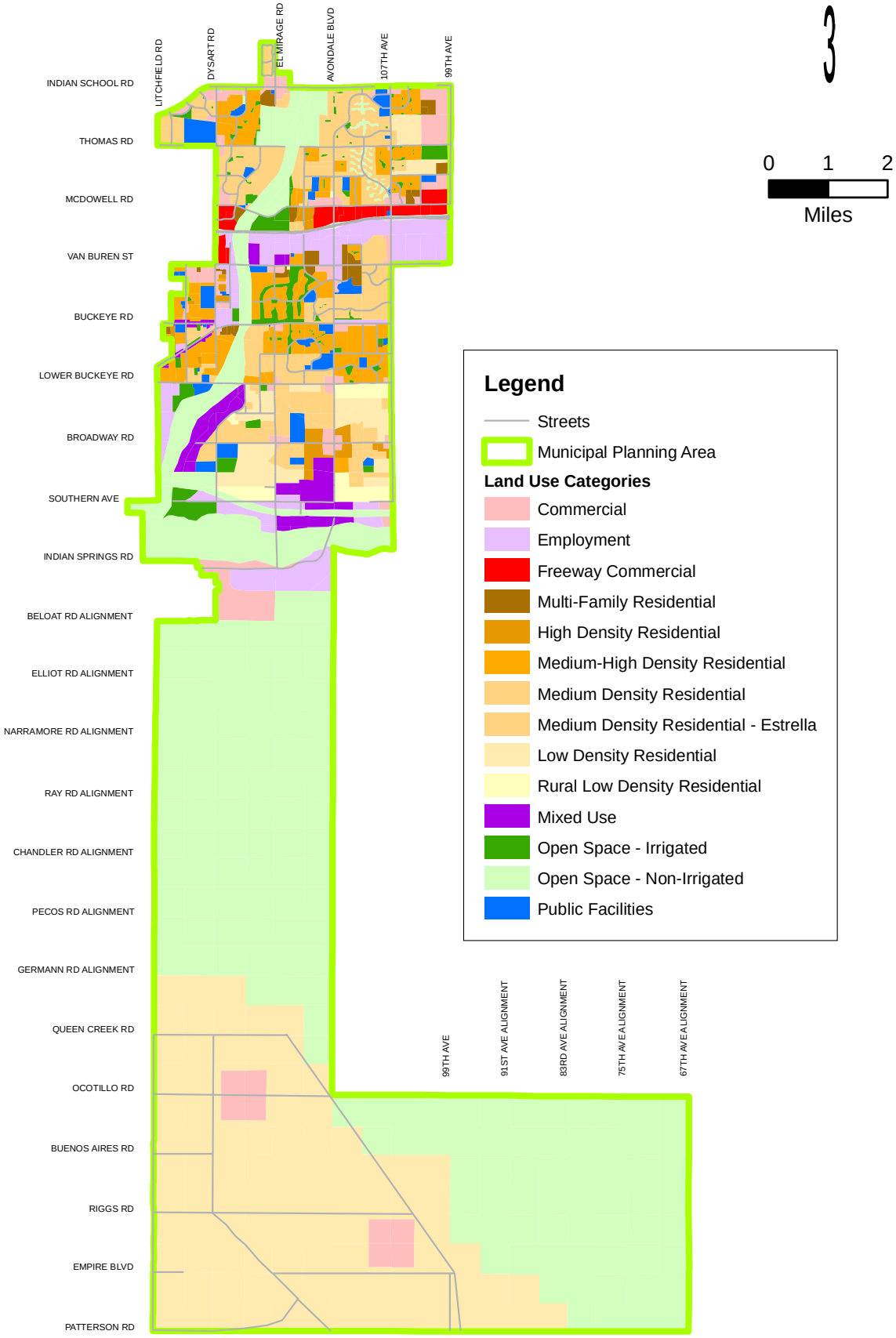
Because the land use classifications will influence water demands, the City made two additional adjustments to the 2002 General Plan land uses:

- *Open Space* was subdivided into *Open Space – Irrigated* (OS-I) and *Open Space – Non-Irrigated* (OS-NI) to differentiate between parks which require water and river beds which do not.
- *Medium Density Residential* was subdivided into *Medium Density Residential* (MDR for areas north of Lower Buckeye Road), and *Medium Density Residential – Estrella* (MDRE) for areas south of Lower Buckeye Road). This will allow the projections to accommodate the lower range residential densities planned for the Estrella Foothills area and the mid-range densities north of Lower Buckeye Road.

6.3.2. Development of Land Use Map

Using the above land use classifications, the land use map shown on Figure 6-1 was developed that reflects the most up to date information on existing and planned land uses within the City's MPA. Figure 6-2 shows the land use map for the Water Resource Master Plan update study area. The summary below describes how the land use map was developed from existing City GIS data and information. Additional information is included in Appendix C.

- The land use map developed in the 2005 Wastewater Collection System Master Plan & Utility Systems Evaluation was used as a starting point.
- The 2005 land use map was updated based on the City's 2009 Development Progress Map (Appendix A) and associated information on existing and planned developments. The dwelling unit densities listed for the existing and planned residential developments on this map were used to modify land use classifications, if necessary.
- Additional updates to development densities and land use classifications, particularly where development lot counts were unknown in the older parts of the City, were made using recent geo-spatially located water meter data, the City's parcels map, and 2007 aerial photography.
- The land uses south of Lower Buckeye Road were replaced with the land use plan in the 2009 Estrella Foothills Specific Plan. Although this specific plan has not been approved by the City Council, City planning department staff indicated that the upcoming General Plan update will be based on this specific plan for areas south of Lower Buckeye Road. The City also suggested two small modifications to the resulting land use map: changing a RLDR land use category to *Mixed Use* west of the Village Area in the Estrella Foothills area, and adding a strip of *Commercial* land in the Roosevelt Park development.
- The land uses for the City Center area were updated according to the 2008 City Center Specific Plan.



M:\0864025\GIS\MXDs\WRMP Final Report\Figure 6-1 Land Use Map for City MPA.mxd

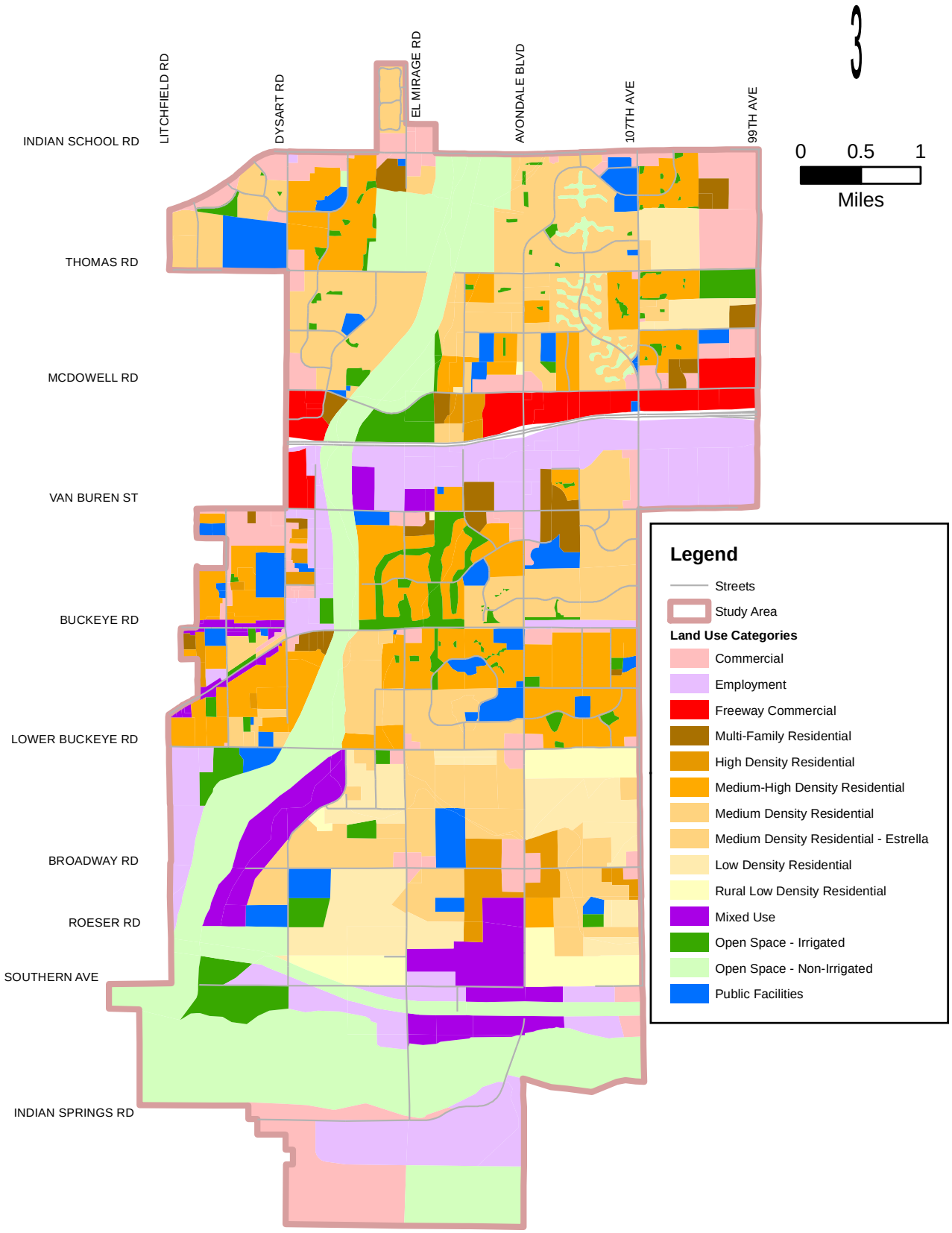
CITY OF AVONDALE, ARIZONA
WATER RESOURCE MASTER PLAN

Land Use Map for City MPA

MALCOLM PIRNIE

May 2010

FIGURE 6-1



M:\0864025\GIS\MXDs\WRMP Final Report\Figure 6-2 Land Use Map for City Study Area.mxd

CITY OF AVONDALE, ARIZONA
WATER RESOURCE MASTER PLAN

Land Use Map for City Study Area

MALCOLM PIRNIE

May 2010

FIGURE 6-2

- All undeveloped and unplanned areas not addressed by any of the above were assigned land uses according the City's 2005 master planning effort.

A summary of the build-out acreages for the resulting land map is presented in Table 6-2.

Table 6-2:
Land Use Map Composition at Build-out

Land Use Classification	Study Area - Area North of Estrella Mountains (Acres)	Area South of Estrella Mountains (Acres)	Percent of Total MPA (%)
Residential	**10,004**	**15,124**	**42%**
Rural Low Density Residential (RLDR)	661	0	1.1%
Low Density Residential (LDR)	1,290	15,124	27%
Medium Density Residential (MDR)	3,508	0	5.8%
Medium Density Residential - Estrella (MDRE)	898	0	1.5%
Medium High Density Residential (MHDR)	2,825	0	4.7%
High Density Residential (HDR)	406	0	0.7%
Multi-Family Residential (MFR)	416	0	0.7%
Non-Residential	**12,054**	**23,146**	**58%**
Commercial (C)	1,852	813	4.4%
Freeway Commercial (FRCO)	553	0	0.9%
Employment (E)	2,420	0	4.0%
Mixed Use (MU)	982	0	1.6%
Open Space – Irrigated (OS-I)	989	0	1.6%
Open Space – Non-Irrigated (OS-NI)	4,311	22,333	44%
Public Facilities (PF)	949	0	1.6%

6.3.3. Population and Growth Projections

The City's population projections for the study area have changed significantly since 2002, both build-out populations and the rate of projected growth. Figure 6-3 presents a comparison of historical population and population projections used in the water supply planning reports discussed in Section 6.1, as well as the current updated population projection provided by the City Finance Department (Appendix A) that incorporates the impacts of the recent economic crisis (i.e., home foreclosures, business closures). As shown on the figure, the estimated population has decreased by approximately nine percent between 2008 and 2009, and the anticipated rate of growth over the next five to ten years is lower than previously projected. ***It should be noted that the water resource projections herein are based on land uses and not population, and the residential projections are based on the most recent information on development densities (du/acre) as discussed in the previous section.***

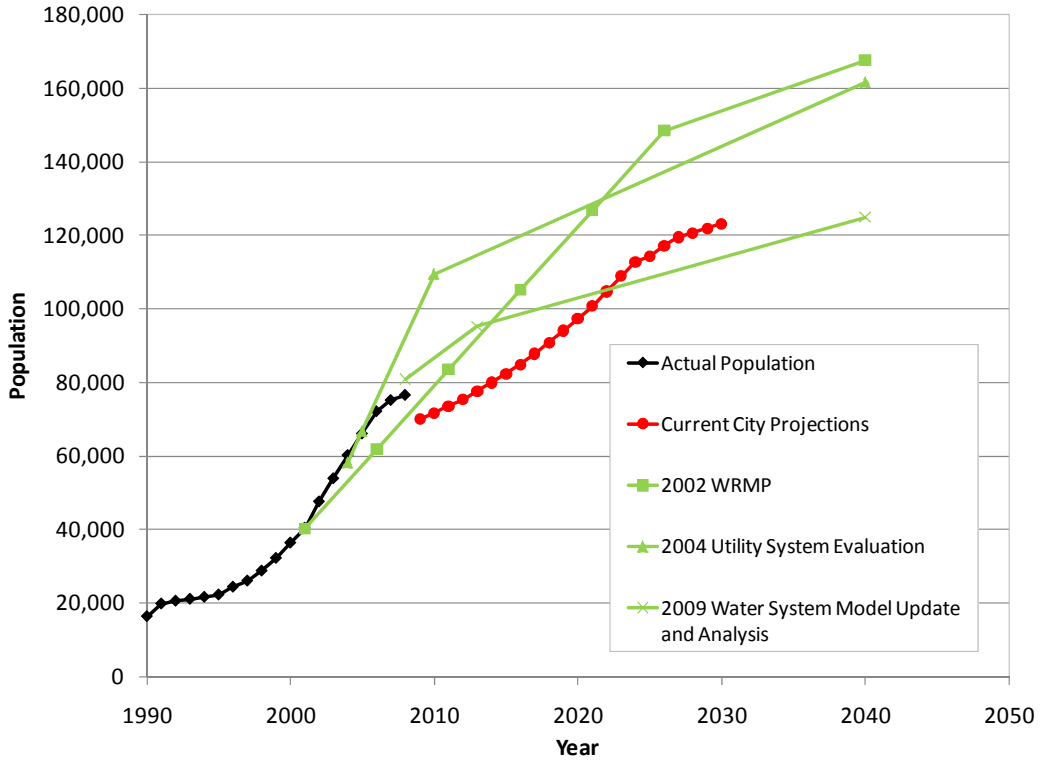


Figure 6-3: Comparison of Population Projections

6.4. Historical Water Use

The City provides water production, distribution, and billing services to customers in the City's current water service area. Based on historical monthly well production data provided by the City, Figure 6-4 shows the annual water production from 1998 through 2008. The figure indicates that a downturn in production was experienced since 2007, most likely due to the impacts of the national economic crisis. This means that recent water demands may be artificially low and recent data should not be used to establish demand factors. Therefore the water demand factors utilized herein were calibrated to 2007 water demands.

Table 6-3 provides a summary of monthly water production and consumption for the time period 2005 through 2009, including monthly production, monthly demands, monthly demand factors (month to annual average), and annual average demand. The table indicates that the maximum month demand generally occurs in July/August with a maximum month to annual average demand factor of 1.4.

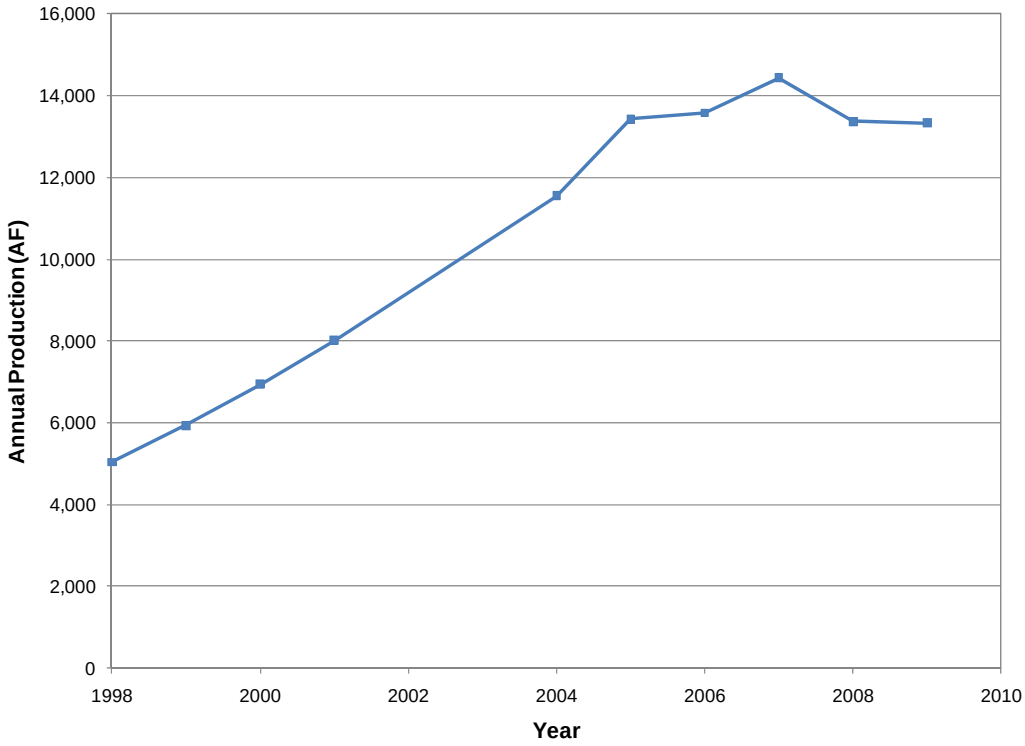


Figure 6-4: Historical Water Production

Table 6-3:
Historical Water Production and Use

Year	2005		2006		2007		2008		2009		Average Month to Annual Average Demand
	Production (AF)[1]	Demand (AF)[2]	Production (AF)[1]	Demand (AF)[2]	Production (AF)[1]	Demand (AF)[2]	Production (AF)[1]	Demand (AF)[2]	Production (AF)[1]	Demand (AF)[2]	
Jan.	539	-- [3]	939	703	925	853	783	721	725	751	0.7
Feb.	516	--	801	804	730	719	699	699	659	653	0.6
Mar.	662	--	806	665	964	731	943	704	881	681	0.8
Apr.	923	--	1,012	863	1,060	922	1,103	1,028	974	948	0.9
May	1,023	--	1,334	1,019	1,383	1,043	1,277	1,181	1,233	1,104	1.1
Jun.	1,334	--	1,459	1,356	1,557	1,355	1,569	1,189	1,365	1,222	1.3
Jul.	1,453	1,277	1,489	1,376	1,661	1,429	1,296	1,524	1,545	1,229	1.4
Aug.	1,187	1,154	1,473	1,425	1,519	1,429	1,433	1,615	1,565	1,504	1.3
Sep.	1,159	1,302	1,156	1,193	1,432	1,333	1,291	1,272	1,333	1,251	1.2
Oct.	1,156	1,016	1,185	1,049	1,189	1,245	1,234	1,284	1,223	1,209	1.1
Nov.	710	953	1,019	993	1,308	1,164	958	1,131	1,018	1,041	0.9
Dec.	977	831	902	945	714	909	784	804	782	880	0.8
Total	**11,640**	**--**	**13,576**	**12,392**	**14,443**	**13,132**	**13,370**	**13,152**	**13,307**	**12,473**	**-**

Notes:
(1) Source: 2005 – 2009 monthly production data
(2) Source: 2006 – 2009 customer billing data
(3) Data not provided

The monthly well production data and customer billing data were also used to determine the City's average non-revenue water which includes any water that was lost in the system prior to the customer due to leaks, unmetered uses, etc. Table 6-4 presents a summary of water production and metered demands, and compares the calculated non-revenue water against non-revenue water that was reported to ADWR. Except for 2008 and 2009, non-revenue water calculated from the water production and customer billing data was similar to those values reported to the ADWR. The differences in the two values arise because the City may make corrections to the billing data and it includes estimates of certain unmetered uses (broken meters, well maintenance, fire department training uses, etc.) in its reports to ADWR. As all of the water demand factors used herein include non-revenue water, the discrepancy shown in the table does not impact development of the Water Resource Master Plan update.

Table 6-4:
Non-Revenue Water

Year	Production (AF)[1]	Metered Demand (AF)[2]	Calculated Non-Revenue Water (%)[1,2]	Reported Non-Revenue Water (%)[3]
2005	11,640	-	-	7.00%
2006	13,576	12,392	8.72%	8.23%
2007	14,443	13,132	9.08%	9.70%
2008	13,370	13,152	1.63%	6.87%
2009	13,307	12,473	6.27%	3.85%

Notes:
(1) 2005 – 2009 monthly production data
(2) 2006 – 2009 metered billing data
(3) Water Resources Inventory.xls (09-09-09) and subsequent City amendments

6.5. Historical Wastewater Flows and Reclaimed Water Production

The City also provides wastewater collection and treatment service to customers in the wastewater service area. Based on daily WRF influent and effluent data provided by the City, a summary of 2007 and 2008 wastewater flows and reclaimed water production is provided in Table 6-5. The table indicates that approximately 95 percent of the wastewater flow becomes reclaimed water, the remaining 5 percent is lost in treatment plant residuals (solids), treatment processes, and evaporation.

Similar to water demand factors, wastewater flow factors will also be calibrated to 2007 flow conditions, and reclaimed water will be estimated as 95 percent of wastewater flows.

Table 6-5:
Historical Wastewater Flows and Reclaimed Water Production

Year	Wastewater Influent Flow [1]		Reclaimed Water Produced [1]		Reclaimed Water Production Factor (%)
	AF	mgd	AF	mgd	
2007	5,485	4.9	5,229	4.7	95%
2008	5,544	5.0	5,246	4.7	95%

Source: 2006 to 2009 daily WRF influent and effluent flows

6.6. Water Demand and Wastewater Flow Factors

As indicated in Section 6.2, the unit water demand factors developed in the 2009 Water System Model Update and the unit wastewater flow factors developed in the 2005 Wastewater Collection System Master Plan & Utility Systems Evaluation (see Table 6-1) were used as the starting point for this Water Resource Master Plan update. Appendix C provides a detailed description of how these demand factors were calibrated and adjusted.

6.6.1. Water Demand Factors

The 2009 Water System Model Update water demand factors were compared to demand factors calculated from recent water billing data and the land use map data previously described.

It should be noted that only 75 percent of the water billing data were geo-located. The remaining 25 percent was not located likely because these meters were for multi-family residential areas, parks, or other locations where street addresses did not directly match the addresses in the billing data. In addition, the billing data analyzed included the artificially low water demand period after 2007. For this reason, only a cursory review of water demand factors was conducted by selecting water meters located in areas designated as being nearly built-out (water billing data appeared to be stable over the review period). Presumably due to the home foreclosures and business closings, much of the billing data showed significant drop-offs in billed water. At the same time, a number of the data also appeared to be increasing significantly in billed water over the same periods, likely due to new home and business occupations that had already been in progress. A comparison of the 2009 Water System Model Update demand factors and the range of values calculated from recent billing data is presented in Table 6-6. The calculated demand factors include non-revenue water (at an average of 6.4 percent) to represent estimated water production needs.

Table 6-6 shows that, except for Rural Low Density Residential, the 2009 Water System Model Update water demand factors fall within the range of water demand factors calculated from more recent water consumption data. However, the calculated demand factors for residential uses on a gallon per day per dwelling unit (gpd/du) basis fall closer

to the 2009 Water System Model Update assumed value of 368 gpd/du. The per-dwelling unit demand factors typically decrease as the development density (du/ac) increases. Table 6-6 shows some of this typical trend.

The results in Table 6-6 also illustrate some of the limitations of projecting residential water demands on a per-acre basis. The demand factor is the same for any value of the development density. For example, the projected demand for 60 acres of Medium Density Residential at 2 du/ac would be the same as 60 acres of Medium Density Residential at 4 du/ac. ***For this reason, the residential water and wastewater demand projections in this Water Resource Master Plan update will be based on per-dwelling unit (gpd/du) demand and flow factors.***

Table 6-6:
Comparison of Water Demand Factors

Land Use Type	2009 Water System Model Update Water Demand Factor (gpad)[1]	Recent Water Demand Factors[2]	
		(gpad)	(gpd/du)
Rural Low Density Residential (0.2 du/ac)	74	230 – 366	367 – 607
Low Density Residential (1 du/ac)	368	350 – 949	353 – 378
Medium Density Residential (3.75 du/ac)	1,378	563 – 3,562	178 – 1,038
Medium High Density Residential (4 du/ac)	1,470	1,082 – 3,484	247 – 596
High Density Residential (8 du/ac)	2,940	1,395 – 2,403	162 – 279
Multi-Family Residential (12 du/ac)	4,410	1,271 – 7,561	56 – 1,020
Commercial	1,850	347 – 4,666	-
Employment	1,000	91 – 3,934	-
Freeway Commercial	1,300	555 – 3,614	-
Public Facilities	1,100	192 – 2,983	-
Open Space - Irrigation	2,300	-	-
Mixed Use	2,230[3]	511 – 2,231	-

Notes:
(1) Residential factors based on 3.5 residents/du and 105 gpcd, or 368 gpd/du; all factors includes non-revenue water (2009 Water System Model Update)
(2) Based on 2006 – 2009 consumption data and 6.4 percent average non-revenue water
(3) Calculated from typical mix of land uses per square mile of *Mixed Use*

Starting with the 2009 Water System Model Update water demand factors, the GIS water resource projection tool was calibrated to match 2007 (existing) water demands. The calibrated water demand factors used for the purposes of this master planning effort are shown in Table 6-7.

Table 6-7:
Calibrated Water Demand Factors

Land Use Category	Units	Initial Water Demand Factor[1]	Calibrated Water Demand Factor
Commercial	gpd/acre	1,850	1,850
Employment	gpd/acre	1,000	1,000
Freeway Commercial	gpd/acre	1,300	1,300
Mixed Use	gpd/acre	2,230	2,230
Open Space (Irrigated)	gpd/acre	2,300	2,300
Open Space (Non—Irrigated)	gpd/acre	0	0
Public Facilities	gpd/acre	1,000	1,000
Rural Low Density Residential	gpd/du	368	361
Low Density Residential	gpd/du	368	361
Medium Density Residential	gpd/du	368	361
Medium Density Residential - Estrella	gpd/du	368	361
Medium High Density Residential	gpd/du	368	361
High Density Residential	gpd/du	368	361
Multi-Family Residential	gpd/du	368	361

Notes:
(1) 2009 Water System Model Update

6.6.2. Wastewater Flow Factors

Since wastewater flow monitoring has not been conducted since 2005, the 2005 Wastewater Collection System Master Plan & Utility Systems Evaluation wastewater flow factors were not assessed with more recent data. The 2005 wastewater flow factors were instead used as the starting point to calibrate the GIS water resource projection tool to existing (2007) wastewater flow conditions. The calibrated wastewater flow factors used for this master planning effort are presented in Table 6-8.

6.7. Baseline Water Resource Projections

6.7.1. Projections for Study Area

Appendix C provides a detailed description of how the water resource projection tool was developed and calibrated. The resulting tool represents the “Baseline” development scenario. Table 6-9 presents the water, wastewater, and reclaimed water projections for SRP On- and Off-Project Areas within the study area. Table 6-10 presents the projections by Service Area and Future Service Area Lands. Table 6-11 presents the projections by land use classifications.

Table 6-8:
Calibrated Wastewater Flow Factors

Land Use Category	Units	Initial Wastewater Flow Factor[1]	Calibrated Wastewater Flow Factor
Commercial	gpd/acre	629	629
Employment	gpd/acre	610	610
Freeway Commercial	gpd/acre	442	442
Mixed Use	gpd/acre	758	758
Open Space (Irrigated)	gpd/acre	0	0
Open Space (Non—Irrigated)	gpd/acre	0	0
Public Facilities	gpd/acre	150	150
Rural Low Density Residential	gpd/du	228	163
Low Density Residential	gpd/du	228	163
Medium Density Residential	gpd/du	228	163
Medium Density Residential - Estrella	gpd/du	228	163
Medium High Density Residential	gpd/du	228	163
High Density Residential	gpd/du	228	163
Multi-Family Residential	gpd/du	228	163

Note:
(1) 2005 Wastewater Collection System Master Plan & Utility System Evaluation

6.7.2. Projections for Areas South of Estrella Mountains

In addition to the projections north of the Estrella Mountains (Tables 6-9 though 6-11), the potential additional water resource demand projections at build-out for the MPA south of the Estrella Mountains are as follows:

- Water Demand = 7,802 AFY
- Wastewater Flow = 3,341 AFY
- Reclaimed Water Production = 3,174 AFY

Table 6-9:
Baseline Projections by SRP On-Project and Off-Project Areas

	2010 (AF)	2015 (AF)	2020 (AF)	2030 (AF)	Build-out (AF)
Study Area – On-Project					
Water Demand	7,265	8,660	11,042	12,879	12,892
Wastewater Flow	2,739	3,278	4,132	4,966	4,970
Reclaimed Water Production	2,602	3,114	3,925	4,717	4,722
Study Area – Off-Project					
Water Demand	7,199	8,585	10,407	15,502	16,681
Wastewater Flow	2,736	3,329	4,045	5,866	6,236
Reclaimed Water Production	2,599	3,162	3,843	5,573	5,924
TOTAL					
Water Demand	14,464	17,245	21,449	28,381	29,572
Wastewater Flow	5,475	6,607	8,177	10,832	11,206
Reclaimed Water Production	5,201	6,277	7,768	10,290	10,645
Incidental Recharge[1]	641	764	950	1,257	1,310

Note:
(1) Incidental recharge is 4.43 percent of the total water demand.

Table 6-10:
Baseline Projections by Service Area and Future Service Area Lands

	2010 (AF)	2015 (AF)	2020 (AF)	2030 (AF)	Build-out (AF)
Study Area – Service Area Lands					
Water Demand	14,464	15,251	15,499	15,935	16,012
Wastewater Flow	5,475	5,824	5,928	6,106	6,123
Reclaimed Water Production	5,201	5,533	5,631	5,801	5,817
Study Area – Future Service Area Lands					
Water Demand	0	1,994	5,950	12,446	13,560
Wastewater Flow	0	783	2,249	4,726	5,083
Reclaimed Water Production	0	744	2,137	4,489	4,828
TOTAL					
Water Demand	14,464	17,245	21,449	28,381	29,572
Wastewater Flow	5,475	6,607	8,177	10,832	11,206
Reclaimed Water Production	5,201	6,277	7,768	10,290	10,645
Incidental Recharge[1]	641	764	950	1,257	1,310

Note:
(1) Incidental recharge is 4.43 percent of the total water demand.

Table 6-11:
Baseline Water Demand Projections by Land Use Classification

	2010 (AF)	2015 (AF)	2020 (AF)	2030 (AF)	Build-out (AF)
Study Area					
Commercial	672	1,307	2,020	3,387	3,688
Employment	441	768	1,657	2,454	2,705
Freeway Commercial	403	534	694	805	805
Mixed Use	223	308	586	2,023	2,452
Open Space (Irrigated)	1,500	1,591	1,774	2,370	2,548
Open Space (Non—Irrigated)	0	0	0	0	0
Public Facilities	725	751	798	900	932
Rural Low Density Residential	42	55	87	121	121
Low Density Residential	190	264	338	568	568
Medium Density Residential	3,555	3,981	4,540	4,814	4,814
Medium Density Residential - Estrella	0	152	305	726	726
Medium High Density Residential	5,193	5,313	5,366	5,420	5,420
High Density Residential	357	586	810	1,347	1,347
Multi-Family Residential	1,161	1,636	2,474	3,446	3,446
TOTAL	14,464	17,245	21,449	28,381	29,572

THIS PAGE INTENTIONALLY LEFT BLANK

7. Comparison of Water Demands and Supplies

The GIS projection tool (described in Appendix C) was developed with the capability to evaluate water demand and supply balances for various development scenarios. This section presents an overview of the development scenarios that were evaluated, describes how the GIS tool was structured to represent each development scenario and evaluation result, and the decisions made for completion of the Water Resource Master Plan update.

7.1. Development Scenarios

Potential development scenarios were discussed at several workshops with City water resources and planning staff. The development scenarios were evaluated only for the study area. The following scenarios were selected for evaluation as a result of the discussions:

- **Baseline Scenario:** This scenario corresponds to the land use and population projections that are currently being discussed for the next update of the City's General Plan. The scenario includes incorporation of the City Center and Estrella Foothills Specific Plans. Appendix C provides a detailed description of how the land use map, previously presented on Figure 6-2, was developed from this current planning information. This scenario also includes a development (dwelling units) growth rate that closely matches the population growth rate provided by the City (Appendix A). Figure 7-1 shows the projected development growth rate for the Baseline scenario.
- **High Growth Rate Scenario:** This scenario considers a higher development growth rate than is currently being discussed for the General Plan update. Figure 7-1 also shows the assumed growth rate for this scenario which includes a high growth rate over the next five years (an approximate 6 percent per year growth rate from now until 2015), then tapering off to the projected build-out dwelling units.
- **Low Growth Rate Scenario:** This scenario considers a lower development growth rate than is currently being discussed for the General Plan update. Figure 7-1 also shows the assumed growth rate for this scenario which includes a zero growth rate over the next five years (to 2015), then slowly ramping up to the projected build-out dwelling units.
- **No State Route 801 Scenario:** This scenario assumes that the proposed State Route 801 in the Estrella Foothills area is eliminated from future implementation. If this occurs, City planning staff indicated that the land use plan would revert back to its previous land use plan (described in the 2005 Wastewater Collection System Master

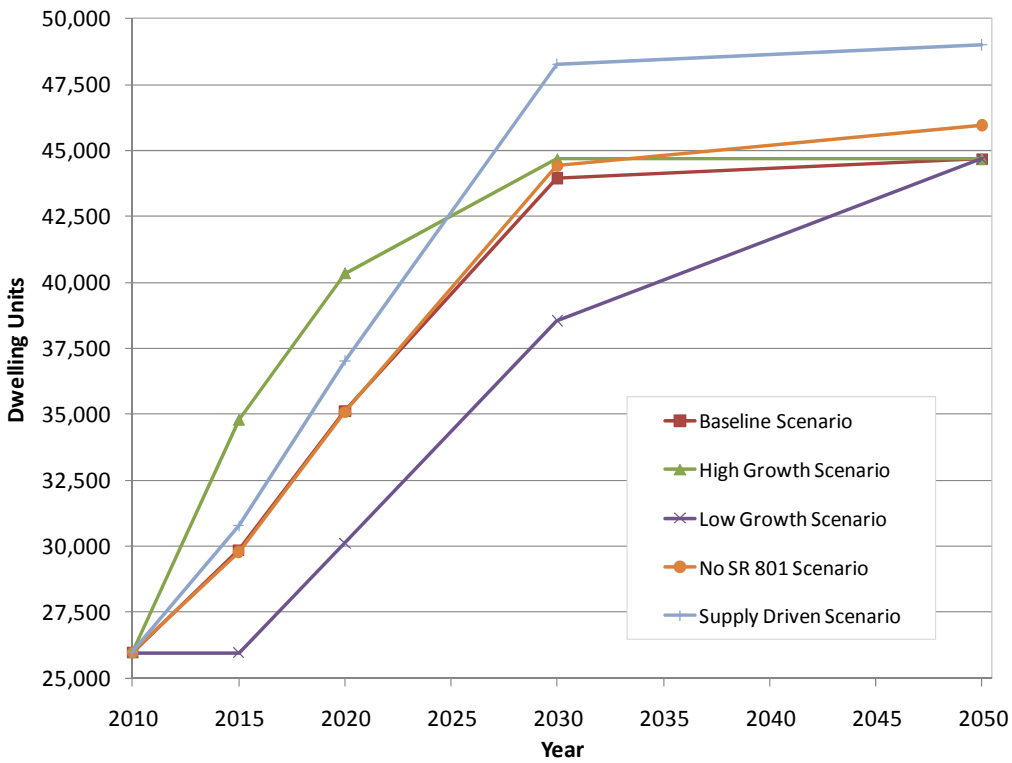


Figure 7-1: Water Resource Scenario Development Growth Projections

Plan & Utility Systems Evaluation). This scenario would, however, consider the current projected growth rate being discussed for the Baseline Scenario.

- **Water Supply Driven Scenario:** This scenario was developed to assess the level of development (additional dwelling units) that could be supported by available water supplies. The residential development densities (du/acre) in undeveloped areas were increased to assess the level of additional development that could be supported.

7.2. Supply/Demand Assumptions

Based on the conclusions reached in Section 5 regarding potential future water supplies, the available water supplies considered for each development scenario did not change and generally included current and future SRP entitlements, current CAP allocations, current balances of groundwater allowances and storage credits distributed over 100 years, current and future reclaimed water, and the potential future White Mountain Apache Indian water lease (refer to Table 5-1). The available water supplies also included the water shortage considerations for SRP and CAP water supplies discussed in Section 5.7.

The evaluations contained in this Water Resource Master Plan update provide a conservative assessment of potential demand/supply balances. The evaluations do not consider the accrual of excess water as long-term storage credits due to the uncertainty of how water supplies will actually be managed in the future. The evaluations also do not

consider excess groundwater pumping (i.e., CAGRD). Finally, the supply/demand balances consider water shortage conditions occurring at each time period, even though the probability of this occurring is considered very low.

A key parameter used in the GIS demand projection tool is the build-out date. The City uses information from the financial planning department to project population over time. Although the population projections provided by the City did not extend beyond 2030, the City provided guidance that an estimate of 2050 for a build-out date (i.e., 100 percent land coverage) is a reasonable assumption for planning purposes. If the development timelines and build-out date change, the resulting water demand and supply comparisons presented herein will also change.

As described in Appendix C, land use acreages and residential densities were adjusted to calibrate the GIS demand projection tool to closely match the projected number of residential dwelling units provided in the various land use planning documents used to develop the updated land use map. The resulting growth rates and number of projected dwelling units are provided in the description of each development scenario. Although resulting populations could be calculated based on assumed factors for residents per dwelling unit, population estimates are not given because of the range of factors used by the various planning agencies (MAG, City General Plan, City Planning Department, etc.).

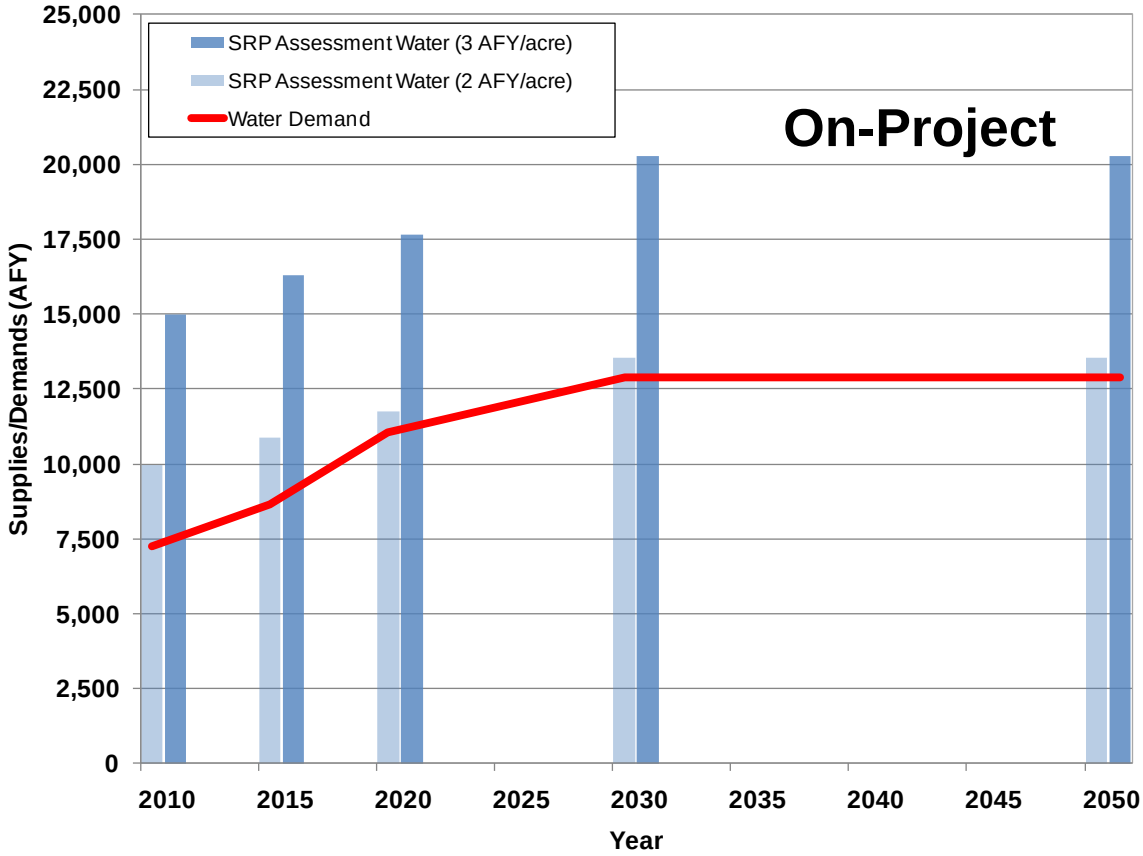
7.3. Baseline Scenario

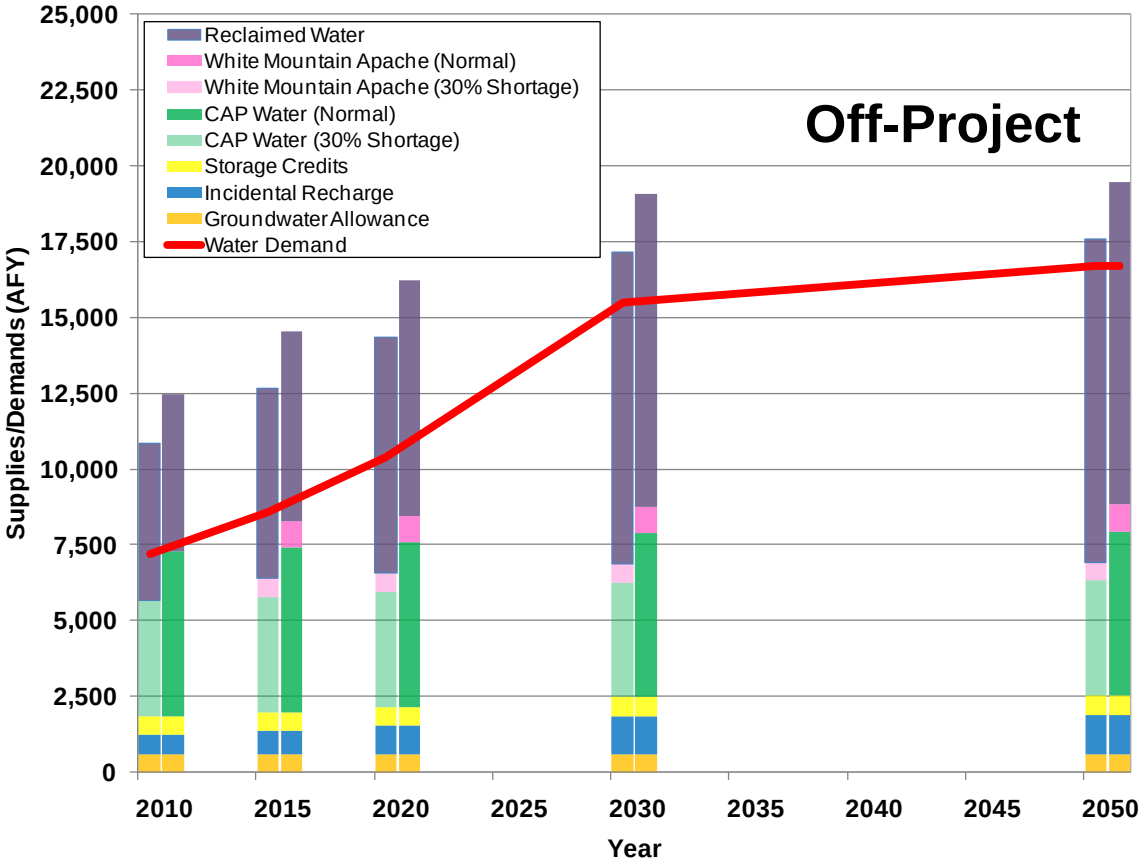
As indicated earlier, this scenario corresponds to the land use and population projections that are being discussed for the next update of the City's General Plan. A summary of the modeled growth in dwelling units for the Baseline Scenario is presented in Table 7-1.

Table 7-1:
Baseline Scenario Growth Projections

Planning Year	Growth	Dwelling Units
2010	-	25,964
2015	15%	29,854
2020	18%	35,136
2030	25%	43,956
2050	2%	44,681

The resulting water demand and supply balance for the Baseline Scenario is shown on Figure 7-2. The projected build-out On-Project Area water demand is approximately 12,900 AFY. The projected build-out Off-Project Area water demand is approximately 16,700 AFY. Figure 7-2 indicates that the available water supplies for both study area On- and Off-Project Areas are generally sufficient to support the planned development





CITY OF AVONDALE, ARIZONA
WATER RESOURCE MASTER PLAN

Baseline Scenario Demand/Supply Comparison

May 2010

Figure 7-2

through build-out for the Baseline Scenario, even with the water shortage conditions considered.

7.4. High Growth Scenario

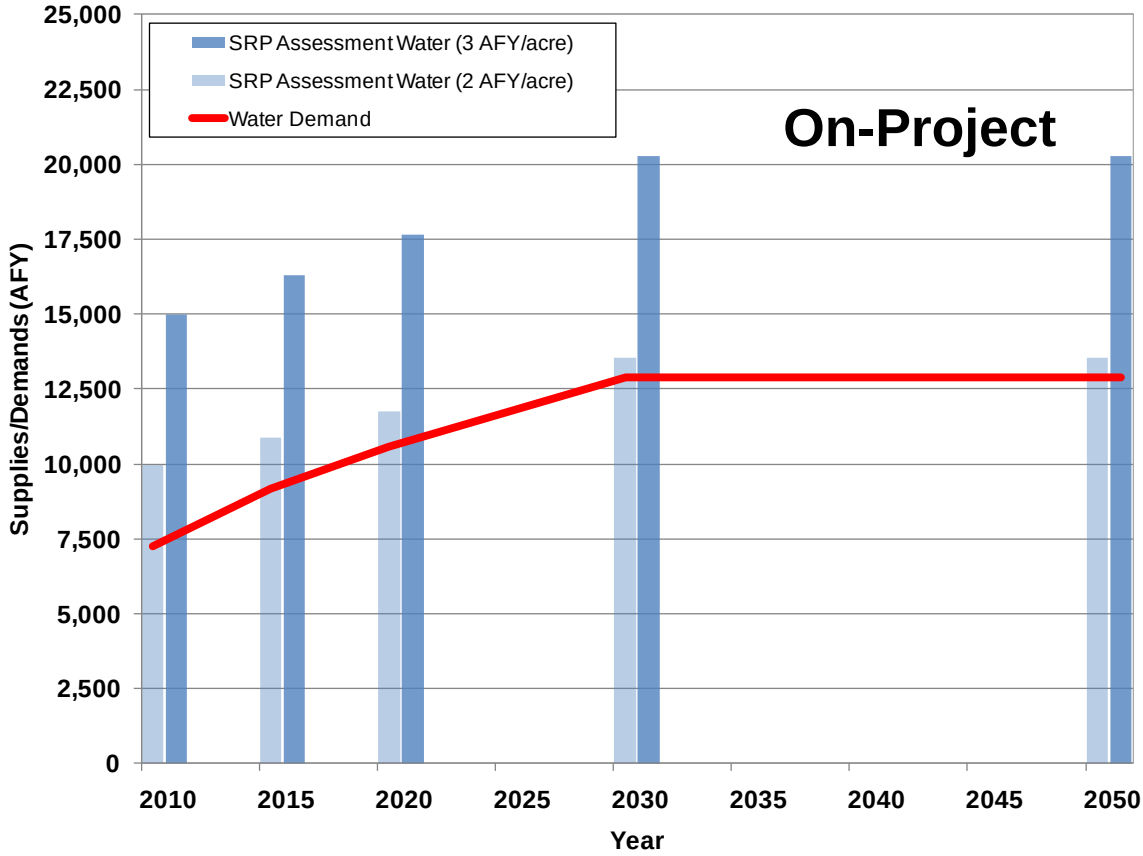
As indicated earlier, this scenario considers a higher growth rate than is being discussed for the General Plan update, including a particularly high growth rate (6 percent per year) from now until 2015. To achieve the alternative growth rate, the percent developed estimates for undeveloped areas were adjusted until the desired rate of development (dwelling units) was achieved. Since it is largely undeveloped, the Estrella Foothills area growth rates received the most adjustments to achieve the overall higher growth rate. A summary of the modeled growth in dwelling units for the High Growth Scenario is presented in Table 7-2.

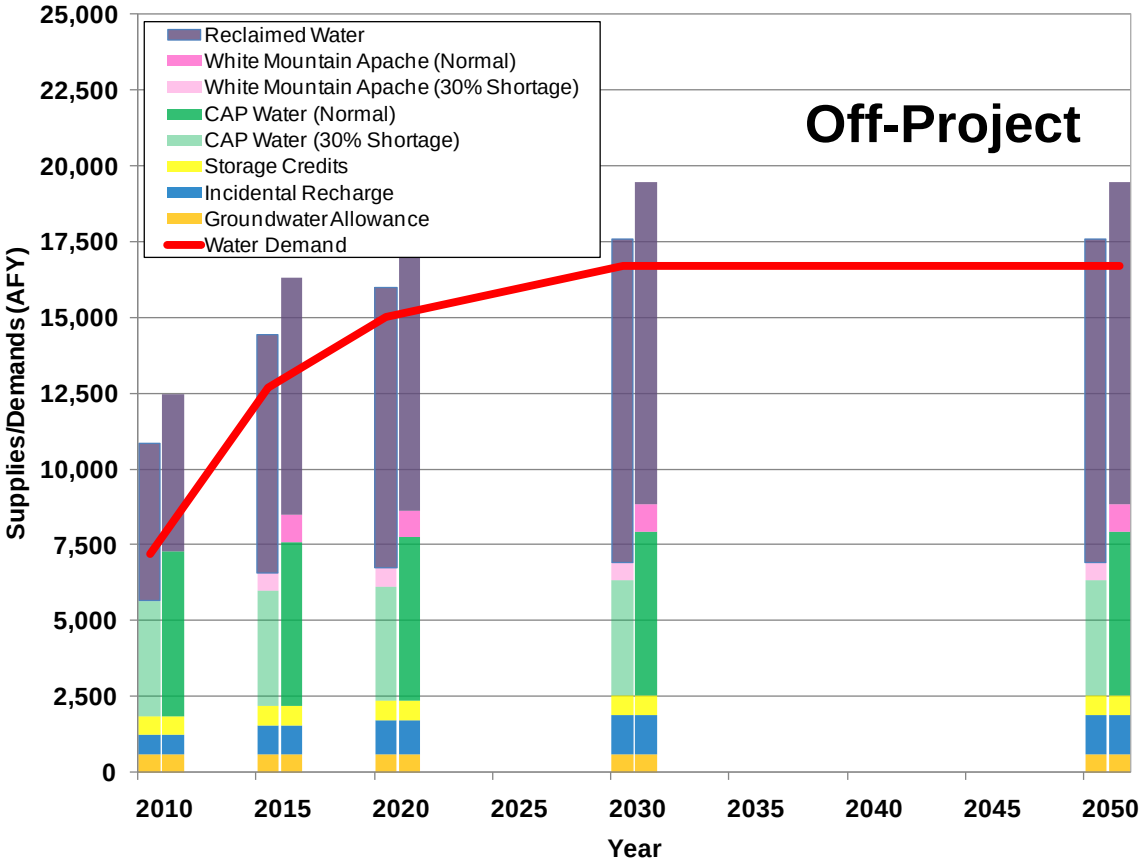
Table 7-2:
High Growth Scenario Growth Projections

Planning Year	Growth	Dwelling Units
2010	-	25,964
2015	34%	34,792
2020	16%	40,358
2030	22%	44,681
2050	0%	44,681

The resulting water demand and supply balance for the High Growth Scenario is shown on Figure 7-3. The projected build-out water demands for On-Project and Off-Project Areas remain unchanged at 12,900 AFY and 16,700 AFY, respectively, with the only change being the rate at which build-out is achieved. With the rate of development primarily affecting the Estrella Foothills area, there is essentially no difference in growth of water demands for On-Project Areas compared with the Baseline Scenario. Under the High Growth Scenario, water demands for Off-Project Areas are projected to reach build-out approximately 20 years earlier than the Baseline Scenario.

Figure 7-3 indicates that the available water supplies for both study area On- and Off-Project Areas are generally sufficient to support the planned development through build-out for the High Growth Scenario, even with the water shortage conditions considered. In Off-Project Areas, however, there will be less surplus water supplies prior to 2030 as compared to the Base Scenario due to greater water demands during the high growth period.





CITY OF AVONDALE, ARIZONA
WATER RESOURCE MASTER PLAN

High Growth Scenario Demand/Supply Comparison

May 2010

Figure 7-3

7.5. Low Growth Scenario

As indicated earlier, this scenario considers a lower growth rate than is being discussed for the General Plan update, including a zero growth rate from now until 2015. To achieve the alternative growth rate, the percent developed estimates for undeveloped areas were also adjusted until the desired rate of development was achieved. Again, since it is largely undeveloped, the Estrella Foothills area growth rates received the most adjustments to achieve the overall lower growth rate. A summary of the modeled growth in dwelling units for the Low Growth Scenario is presented in Table 7-3.

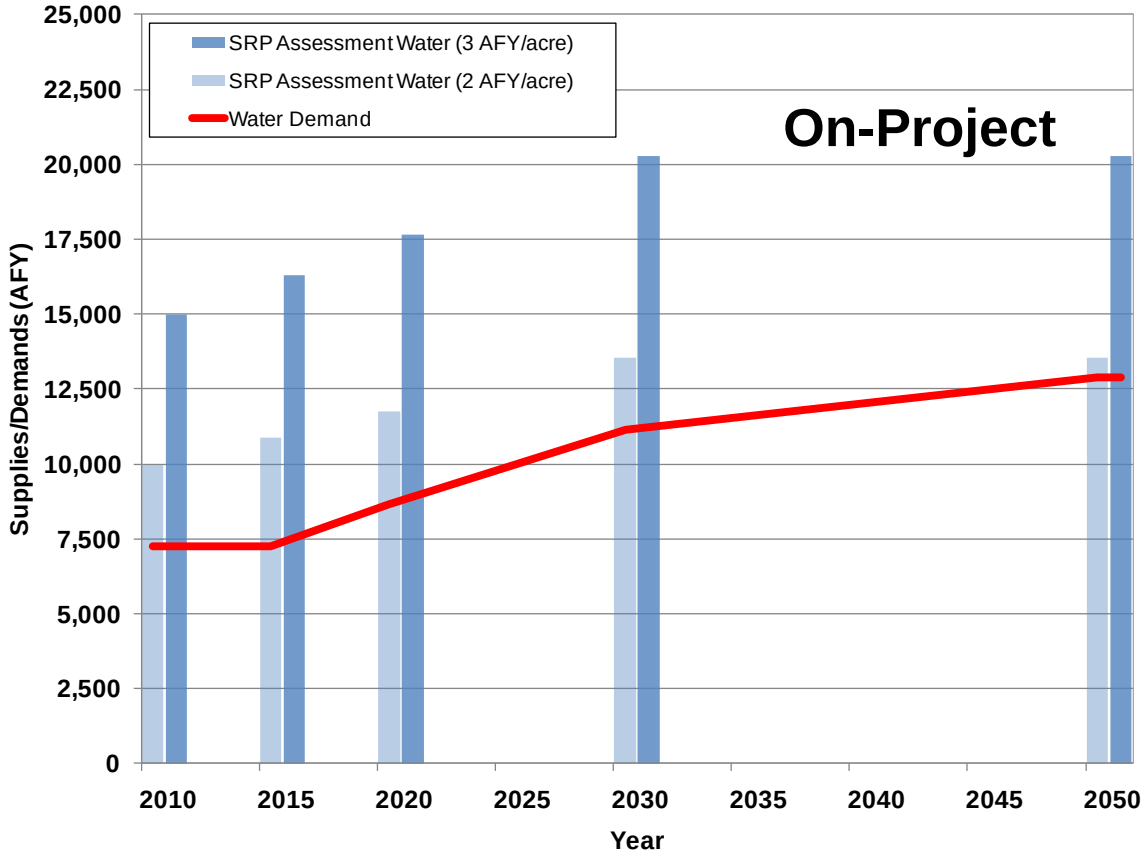
Table 7-3:
Low Growth Scenario Growth Projections

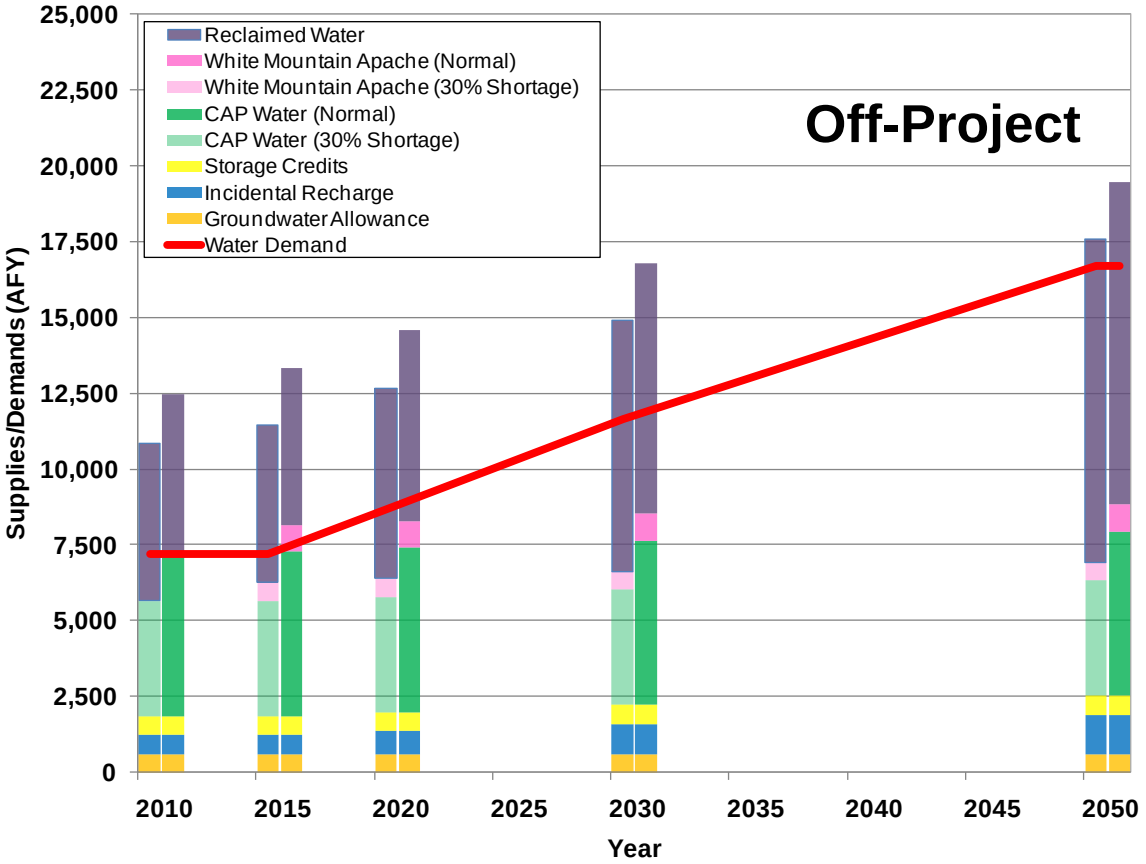
Planning Year	Growth	Dwelling Units
2010	-	25,964
2015	0%	25,964
2020	16%	30,118
2030	28%	38,551
2050	16%	44,681

The resulting water demand and supply balance for the Low Growth Scenario is shown on Figure 7-4. The projected build-out water demands for On-Project and Off-Project Areas also remain unchanged at 12,900 AFY and 16,700 AFY, respectively, with the only change being the rate at which build-out is achieved. Figure 7-4 indicates that the available water supplies for both study area On- and Off-Project Areas are generally sufficient to support the planned development through build-out for the Low Growth Scenario, even with the water shortage conditions considered. In Off-Project Areas, however, there will be more surplus water supplies through build-out as compared to the Baseline Scenario due to lower water demands during the slow growth period.

7.6. No State Route 801 Scenario

As indicated earlier, this scenario assumes that the proposed State Route 801 in the Estrella Foothills area is eliminated from future implementation. In November 2004, voters in Maricopa County approved an extension to an existing sales tax funding transportation improvements, with a significant portion of the funds to go toward improvements of I-10 which experiences significant volumes of traffic in the southwest Valley. However, rapid growth in Avondale, Buckeye, and Goodyear is expected to worsen the congestion on I-10 in spite of improvements, necessitating the construction of a reliever route. Studies by the Arizona Department of Transportation have identified a study area (corridor) running roughly 5 miles south of and parallel to I-10. Construction is not anticipated to begin before 2021 according to current Arizona Department of Transportation planning documents. The Estrella Foothills area will be largely impacted





CITY OF AVONDALE, ARIZONA
WATER RESOURCE MASTER PLAN

Low Growth Scenario Demand/Supply Comparison

May 2010

Figure 7-4

by State Route 801 and it is unlikely that the Estrella Foothills vision will become a reality without the project.

Without State Route 801, it is assumed that land uses would revert back to the 2002 General Plan land uses which projected more residential developments within the Estrella Foothills area. In order to model this scenario, land uses south of Lower Buckeye Road were changed to match those developed in the 2005 Wastewater Collection System Master Plan & Utility Systems Evaluation (the 2005 land use map was derived from the 2002 General Plan). The percent developed estimates for undeveloped areas for all planning years were kept the same as the Baseline Scenario; however, the rate of development changed slightly because of the changes in land use types. A summary of the modeled growth in dwelling units for the No State Route 801 Scenario is presented in Table 7-4.

Table 7-4:
No State Route 801 Scenario Growth Projections

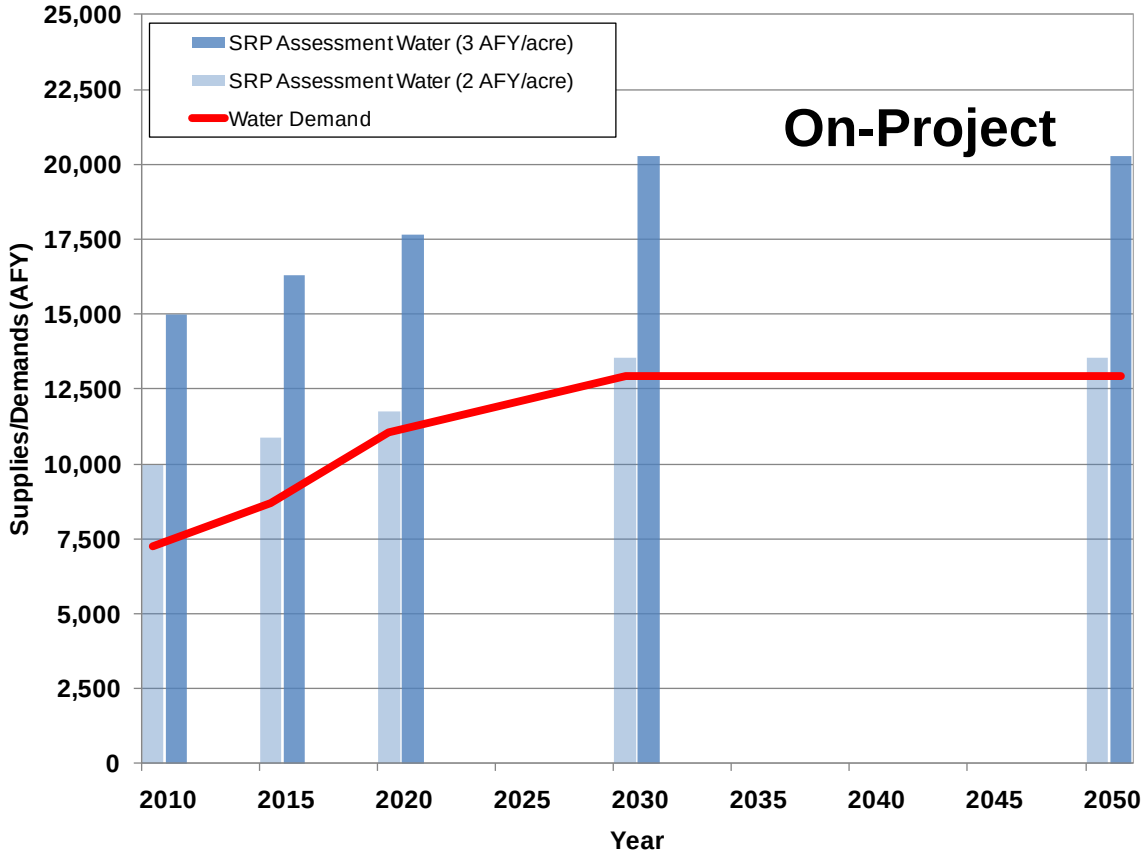
Planning Year	Growth	Dwelling Units
2010	-	25,980
2015	15%	29,784
2020	18%	35,084
2030	27%	44,423
2050	3%	45,958

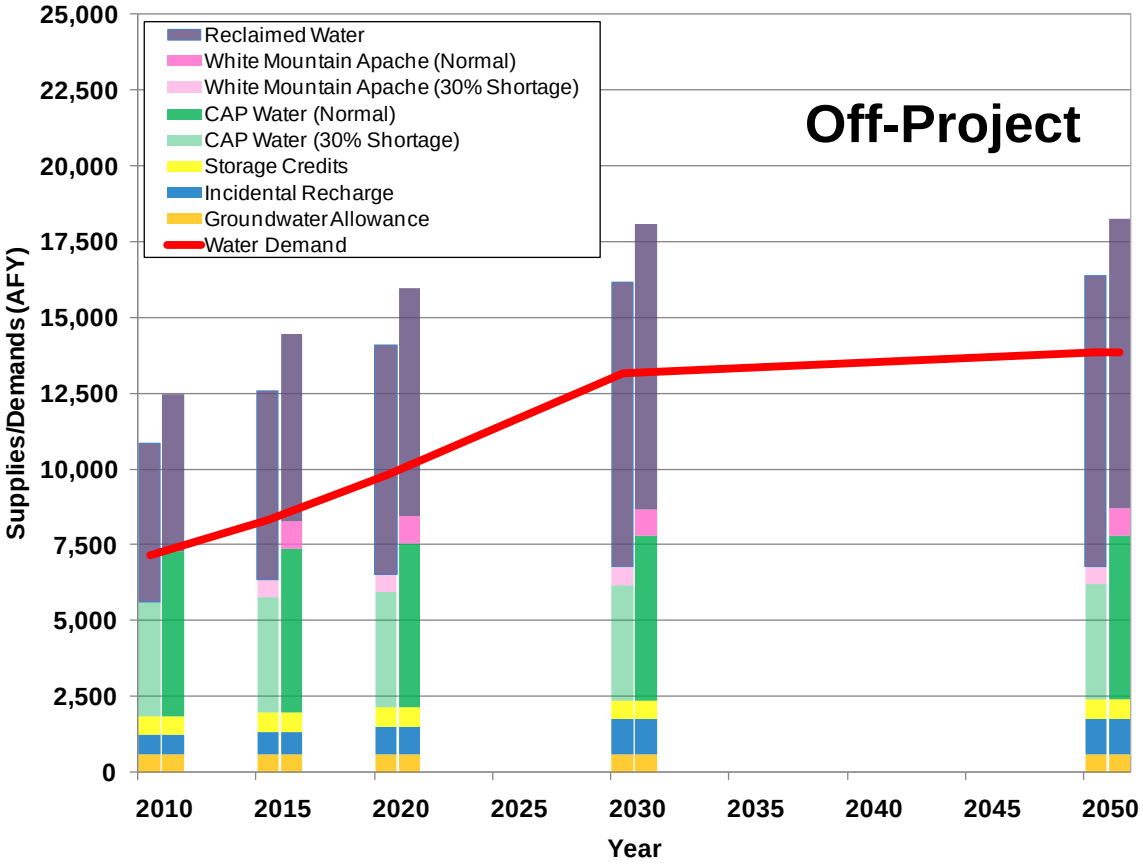
The resulting water demand and supply balance for the No State Route 801 Scenario is shown on Figure 7-5. The projected build-out water demands for On-Project and Off-Project Areas in this scenario are 12,900 AFY and 13,800 AFY, respectively. Since SRP On-Project Areas comprise only a small portion of the undeveloped areas, there was little change in both build-out demand and rate of growth in On-Project Areas. Although the residential acreage in Off-Project Areas is slightly higher (27,600 acres) compared to the Baseline Scenario (25,000 acres), the water demand is less, due to the lower acreage of commercial, mixed use, and open space areas (32,700 acres) compared to the Baseline Scenario (35,300 acres).

Figure 7-5 indicates that the available water supplies for both study area On- and Off-Project Areas are generally sufficient to support the planned development through build-out for the No State Route 801 Scenario, even with the water shortage conditions considered.

7.7. Water Supply Driven Scenario

As indicated earlier, this scenario was developed to assess the level of additional development that could be supported by available water supplies. This scenario was





CITY OF AVONDALE, ARIZONA
WATER RESOURCE MASTER PLAN

No SR 801 Scenario Demand/Supply Comparison

May 2010

Figure 7-5

modeled by using the maximum dwelling unit densities for all residential land use classifications in undeveloped areas. Since the *Multi-Family Residential* classification does not have a maximum density in the General Plan, the density was increased to 24 du/acre in this classification. In addition, only the residential densities in the undeveloped areas (Future Service Area Lands) that are currently unplanned were increased. The undeveloped areas that currently have development plans on file were kept at the densities specified in the development plans. A majority of the undeveloped areas north of Lower Buckeye Road are covered by development plans and close to a third of the area south of Lower Buckeye Road is covered by development plans.

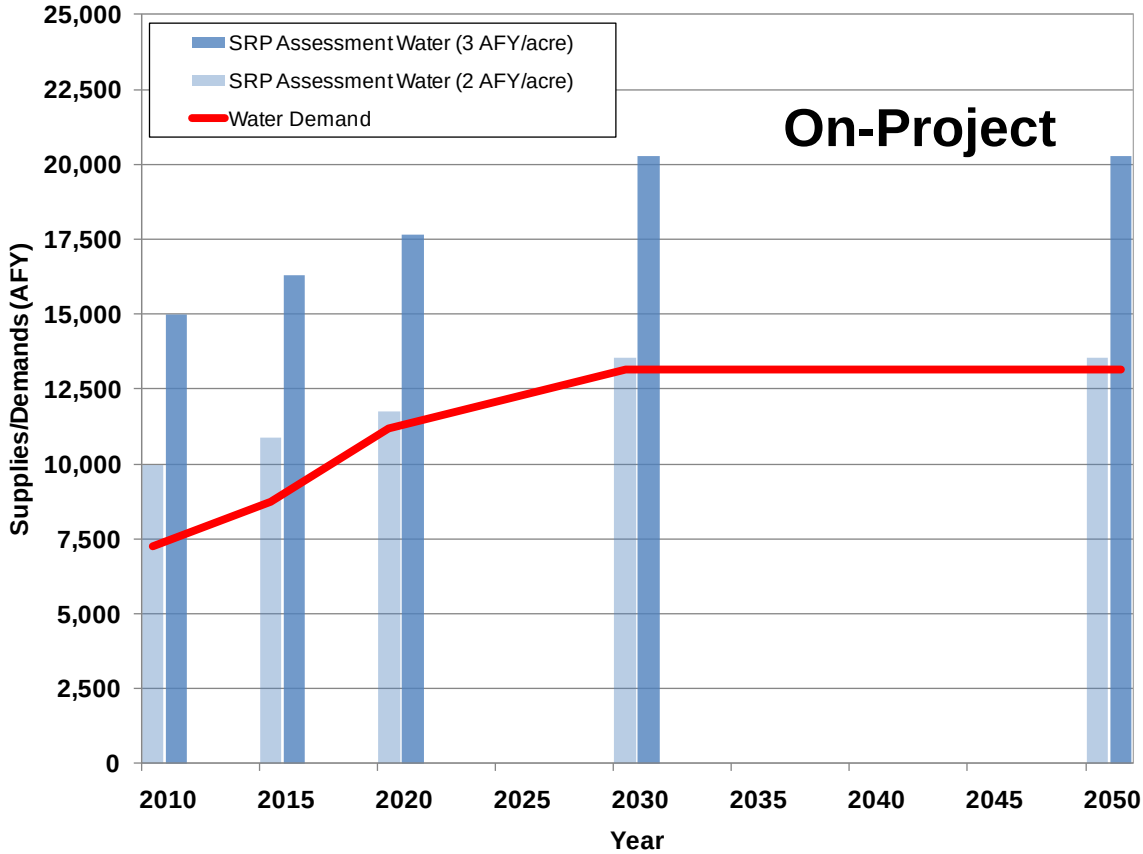
The percent developed estimates for all planning years were kept the same as the Baseline Scenario; however, the rate of development changed slightly because the change in residential dwelling unit densities. A summary of the modeled growth in dwelling units for the Water Supply Driven Scenario is presented in Table 7-5.

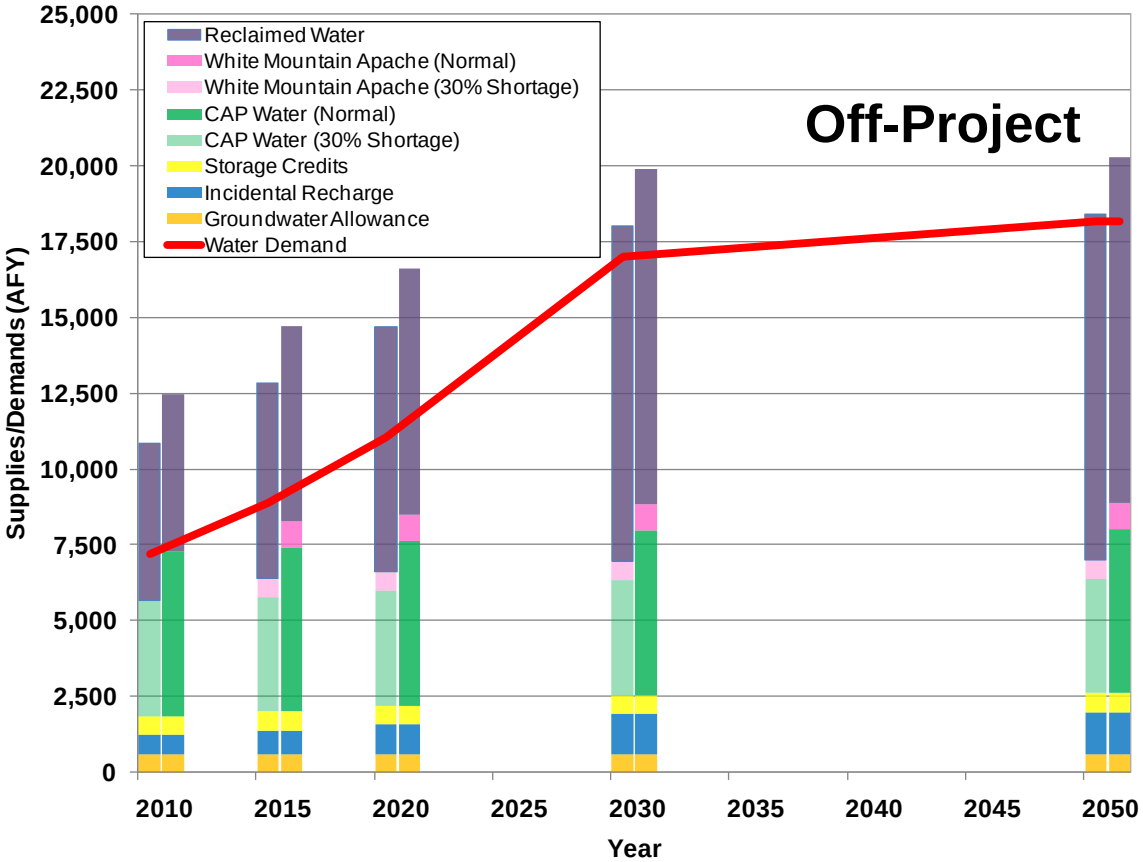
Table 7-5:
Water Supply Driven Scenario Growth Projections

Planning Year	Growth	Dwelling Units
2010	-	25,982
2015	18%	30,777
2020	20%	37,031
2030	30%	48,284
2050	2%	49,009

The resulting water demand and supply balance for the Water Supply Driven Scenario is shown on Figure 7-6. The projected build-out water demands for On-Project and Off-Project Areas in this scenario are 13,200 AFY and 18,200 AFY, respectively. Since only about 32 percent of the SRP On-Project Areas is undeveloped, and about half of that is covered by existing development plans, there was little change in both build-out demand and rate of growth in On-Project Areas. The build-out demand in the Off-Project Areas is only 1,500 AFY higher compared to the Baseline Scenario, again because there is not a lot of undeveloped area that is not covered by existing development plans.

Figure 7-6 indicates that the available water supplies for both study area On- and Off-Project Areas are generally sufficient to support the planned development through build-out for the Water Supply Driven Scenario, even with the water shortage conditions considered. However, the demands closely approach the available supplies at build-out under water shortage conditions in both areas.





CITY OF AVONDALE, ARIZONA
WATER RESOURCE MASTER PLAN

Supply Driven Scenario Demand/Supply Comparison

May 2010

Figure 7-6

Table 7-5 and Figure 7-6 indicate that the available water supplies could support the maximum residential densities allowed, or an additional 4,300 dwelling units at build-out as compared to the Baseline Scenario. The analysis of the Water Supply Driven Scenario indicates that if the City wants to utilize more of the available water supplies, particularly in SRP On-Project Areas, the City would have to modify its land use plans significantly and perhaps even redevelop existing areas to higher densities.

7.8. Development Scenario for Water Resources Planning

The evaluation of potential water demand and supply balances indicates that, in general, the City's available water supplies (current and future SRP entitlements, current CAP allocations, current balances of groundwater allowances and storage credits, current and future reclaimed water, and the potential future White Mountain Apache Indian Lease Water) can support the range of development scenarios envisioned for the study area, even under the water shortage conditions considered.

The conservative approach used in the evaluations indicates that available water supplies could support higher development densities (and a larger population) than currently planned if the City desires:

- The evaluations do not consider accrual of excess water supplies as long-term storage credits.
- The probability of the water shortage conditions evaluated is considered low. Even so, the City's water demands would only come close to the available water supplies under water shortage conditions.
- The evaluations stayed within the confines of the land use plans provided and the range of allowable residential densities.

Based on the conclusions reached, the remainder of the Water Resource Master Plan update and the companion Water Infrastructure Master Plan update will be based on the Baseline Development Scenario.

THIS PAGE INTENTIONALLY LEFT BLANK

8. Water Supply Alternatives and Evaluations

This section describes the identification and evaluation of alternatives for producing and supplying potable water to the City's service area. The first section includes a discussion of preliminary evaluations that were common to one or more alternatives, including prioritization of existing wells for rehabilitation or re-drilling; production and storage requirements; well siting considerations; SRP, CAP and reclaimed water recharge locations; and conceptual hydraulic modeling to size major infrastructure. The sections following include schematic descriptions, hydrogeologic evaluations, cost evaluations, and matrix evaluations to identify a preferred water supply strategy.

The above evaluations were based on preliminary information, including existing well capacities, production and storage requirements, etc., and were conducted to identify a preferred water supply strategy. The selected strategy was further defined and refined to develop the recommended Water Infrastructure Master Plan update. Thus the information presented in this section and Appendices E and F may not match the refined information in the Water Infrastructure Master Plan update.

8.1. Identification of Alternatives

Based on previous water supply planning completed for the City, there are two basic water supply alternatives available to the City: continuing to build wells and building a surface water treatment plant (WTP).

Under the Continue to Build Wells strategy, future wells would be located in the most favorable water quality areas to minimize or avoid groundwater treatment. Future wells will also be located considering potential impacts on nearby contaminant plumes, Avondale Recharge Facility operations, and distribution system pumping. The three Continue to Build Wells alternatives are as follows:

- **Alternative 1:** Focus new wells in the northwest area and east of Dysart Road to assess the potential impacts of production pumping on the PGA North Superfund contaminant plume.
- **Alternative 2:** Focus new wells around the Avondale Recharge Facility to assess the impacts on groundwater mounding and groundwater movement in the vicinity of the facility.
- **Alternative 3:** Site new wells throughout the service area, but north of Buckeye Road (i.e., irrespective of favorable groundwater quality areas) to assess the additional costs of groundwater treatment.

Under the Build a Surface WTP strategy, a WTP would be constructed to treat SRP and CAP water for direct distribution to residents (as opposed to recharge and recovery). Based on the projected SRP On-Project Area demand of 12,892 AFY (11.5 mgd) plus CAP allocation of 5,416 AFY (4.8 mgd), the ultimate capacity of the WTP was assumed to be 15 mgd. The WTP would be operated as a base load plant with peak demands (and demands during plant shutdowns due to SRP canal system maintenance) met by production wells. Two alternatives were evaluated based on two WTP locations provided by the City:

- **Alternative 4:** Build a WTP near the Avondale Recharge Facility
- **Alternative 5:** Build a WTP near 107th Avenue and Roosevelt Street

8.2. Preliminary Investigations

Before the water supply alternatives could be conceptualized for evaluation, several preliminary investigations were conducted to formulate the bases for the evaluations, including prioritization of existing wells for rehabilitation or re-drilling; production and storage requirements; well siting considerations; SRP, CAP and reclaimed water recharge locations; and conceptual hydraulic modeling to size major infrastructure.

8.2.1. Prioritization of Existing Wells for Rehabilitation/Re-drilling

As part of the Water Resource Master Plan update, a hydrogeologic update for the City study area was completed which included a description of local geology, local hydrogeology, and groundwater quality. The purpose of this task was to update the City's groundwater levels maps, geologic cross-sections, and groundwater quality. The hydrogeologic update is included as Appendix D.

Based on the hydrogeologic update, a review of the City's production well data (water quality, well depth, screening interval, etc.) was performed in order to identify existing, inactive production wells that could be rehabilitated or re-drilled in order to target more favorable water quality and reduce or eliminate the need for costly treatment systems. Modifying existing wells would take advantage of existing infrastructure already in place, thereby reducing costs to the City. Based on the hydrogeologic evaluation of existing wells (Appendix D), three productions wells (Wells #1, #8A, and #14) were identified as potential rehabilitation/re-drill candidates:

- **Well #1:** City personnel indicated that Well #1 may have been taken off line due to its proximity to the Western Avenue Water Quality Assurance Revolving Fund (WQARF) groundwater contamination site and possibly due to high nitrate concentrations. Recent data from the Western Avenue WQARF site indicates that the groundwater sampled at the sites monitor wells are below the MCL for the contaminant of concern, perchloroethene. Based on available information, this well

may be a candidate for rehabilitation as a non-treatment alternative for providing additional water supply.

- **Well #8A:** Well #8A has nitrate at approximately 15 mg/L. Zonal, depth specific water quality sampling from nearby Well #24 indicates nitrate exceeds the MCL above a depth of 400 feet with no exceedances below 400 feet. Well # 8A is screened from 289 feet to 635 feet. This information suggests that that the upper 50 to 100 feet of screen in Well #8A could be sealed off to isolate the higher nitrate zones and reduce overall concentrations.
- **Well #14:** This well may be a candidate for re-drilling to target better water quality at shallower depths. Well #14 has high arsenic at approximately 0.015 mg/L. Zonal water quality sampling results from other wells in the general area (Wells #16, #19, and #21) suggest that drilling a new well and screening higher may result in reduced arsenic levels. However, shallower levels of the aquifer may have higher concentrations of nitrate and possibly TDS; therefore, an exploratory boring with a comprehensive zonal sampling program is recommended prior to construction of a replacement well for Well #14.

8.2.2. Production and Storage Requirements

In order to determine the number of new wells and water supply facilities that would be needed under each alternative, water production and storage requirements were determined by comparing the projected water demands (Section 6) against existing facility capacities (Section 4). Because water recovered from SRP On-Project Areas cannot exceed On-Project Area demands, water balance calculations were performed for both On-Project and Off-Project Areas.

According to the City's General Engineering Requirements Manual (2008), total production capacity is governed by two criteria: *total supply* and *reliable supply*. *Total supply* is defined as meeting maximum day demands with the largest well out of service. *Reliable supply* is defined as meeting maximum day demands will all wells operating no more than 18 hours per day.

Based on the production capacity criteria, the existing well capacities, and assuming that each new well will have a capacity of approximately of 1,200 gpm, a total of 11 additional production wells would be needed for the Continue to Build Wells alternatives (Alternatives 1, 2, and 3) through build-out (Appendix E). Figure 8-1 shows how the new wells would be phased in over time based on the water demand projections. In order to satisfy On-Project Area withdrawal limitations (limited to On-Project Area demand) and provide ultimate flexibility, a greater number of new production wells would be located Off-Project.

Based on the production criteria, a total of six additional production wells would be needed for the Build a Surface WTP alternatives (Alternatives 4 and 5) through build-out (Appendix E). Figure 8-2 shows how the new wells would be phased in over time.

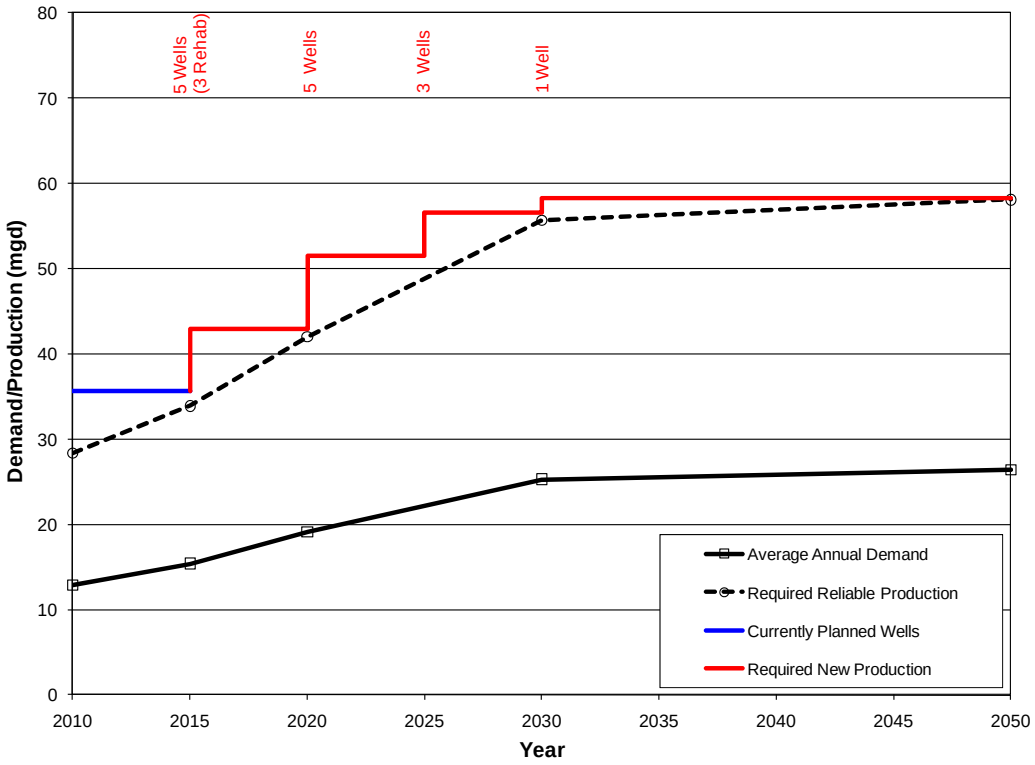


Figure 8-1: Continue to Build Wells: Required Production Phasing

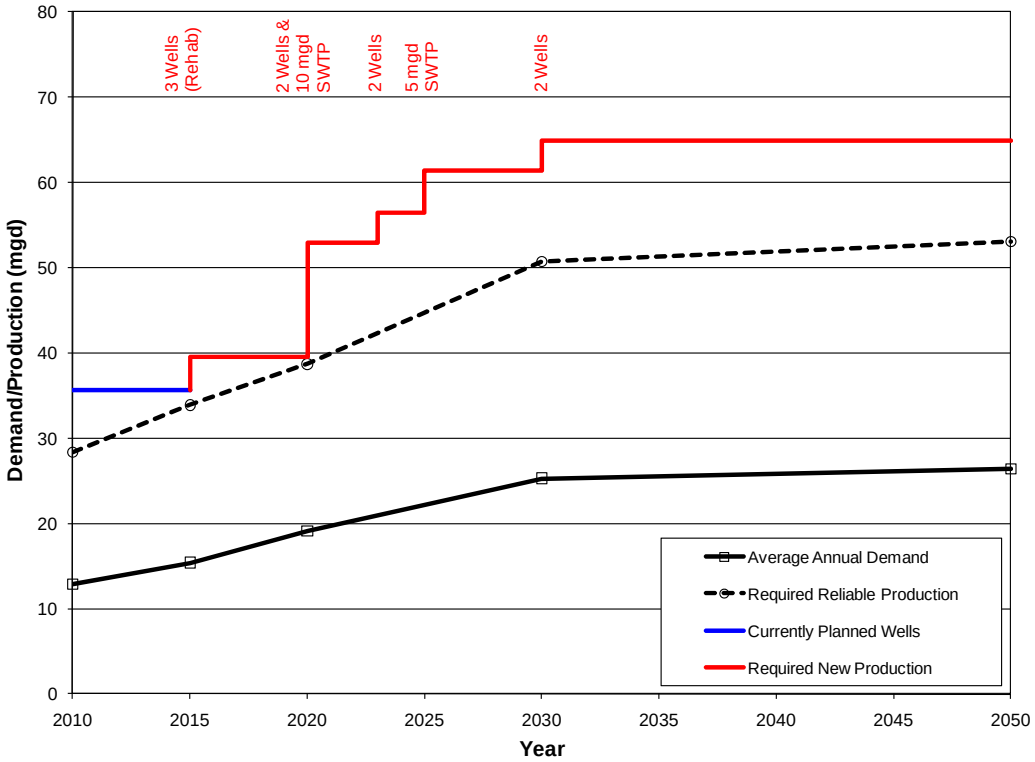


Figure 8-2: Build a Surface WTP: Required Production Phasing

Because the surface WTP would be located On-Project and subject to withdrawal limitations, On-Project Area wells would not be used and there will be excess production capacity On-Project. The six additional production wells located Off-Project will be needed to meet both On-Project and Off-Project area peaking demands. For this reason, the total available supply available at build-out will exceed the reliable supply needed as shown on Figure 8-2.

A surface WTP constructed in the City will have to shut down for a period of time during the winter when the canals receive routine maintenance. In order to ensure the City will have sufficient production wells to meet January 2007 winter demands of 9.9 mgd (Table 6-3; 77 percent of average day demand) during canal shutdown, another analysis was performed using the total and reliable supply criteria. It was found that the number of new production wells needed to meet winter demands (with the surface WTP out of service) were less than those required during maximum day (summer) demands.

Calculations were also performed in order to determine the amount of additional storage needed according to the 2008 General Engineering Requirements Manual. The manual defines four criteria that must be met with the available storage and wells: *peak hour storage, fire flow, operating storage,* and *emergency supply*. Based on the storage criteria, it was determined that the City would not require any additional storage at build-out for any of the alternatives. Storage calculations are provided in Appendix E.

8.2.3. Surface and Reclaimed Water Recharge

In order to identify possible recharge capacity and conveyance restrictions, and to incorporate appropriate infrastructure costs into the evaluations, water balances for surface and reclaimed water were performed for the Continue to Build Wells alternatives (Figure 8-3) and the Build a Surface WTP alternatives (Figure 8-4).

Currently, the City receives its SRP water allotment at a turnout adjacent to the Crystal Gardens Wetlands located in the northeast portion of the study area. The hydraulic capacity of the wetlands is approximately 15,000 AFY (13.4 mgd). According to SRP system maps, the SRP lateral system that feeds the wetlands has a capacity of approximately 10 mgd. Similarly, the capacity of the pipeline from the wetlands to the Avondale Recharge Facility is approximately 10 mgd (Malcolm Pirnie, 2007). Thus, any alternative that includes conveying more than 10 mgd to the wetlands through SRP laterals and more than 10 mgd through the wetlands effluent pipe must include parallel pipelines to increase capacity. The City is also committed to maintaining the Crystal Gardens Wetlands by conveying a minimum operational flow through the wetlands of about 4,000 AFY (Malcolm Pirnie, 2007). Thus, all alternatives will have to maintain this minimum flow through the Crystal Gardens Wetlands.

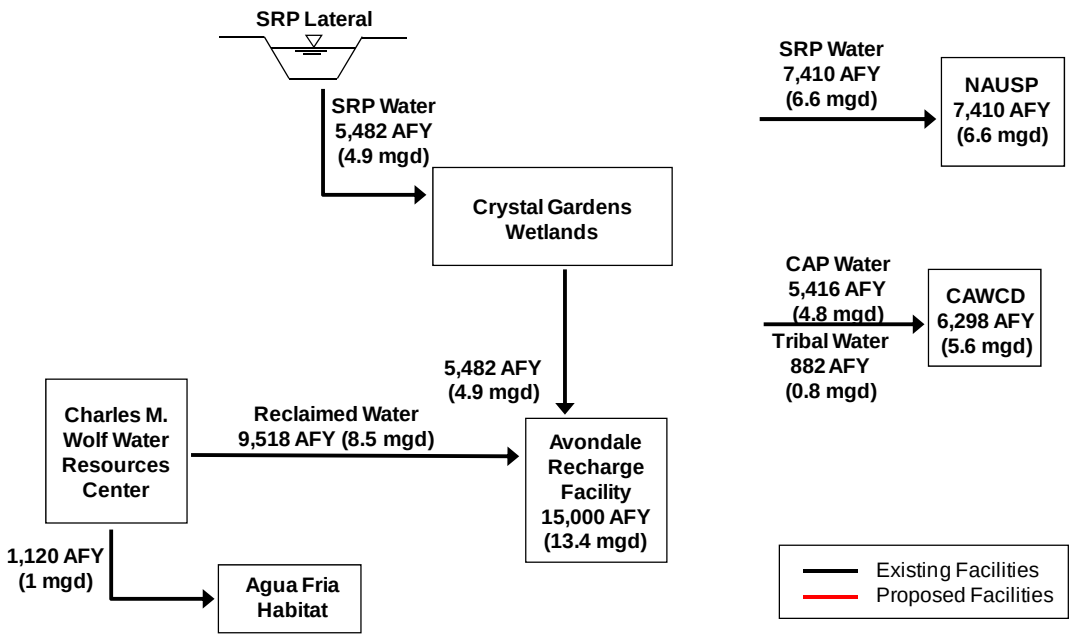


Figure 8-3: Continue to Build Wells: Water Balance

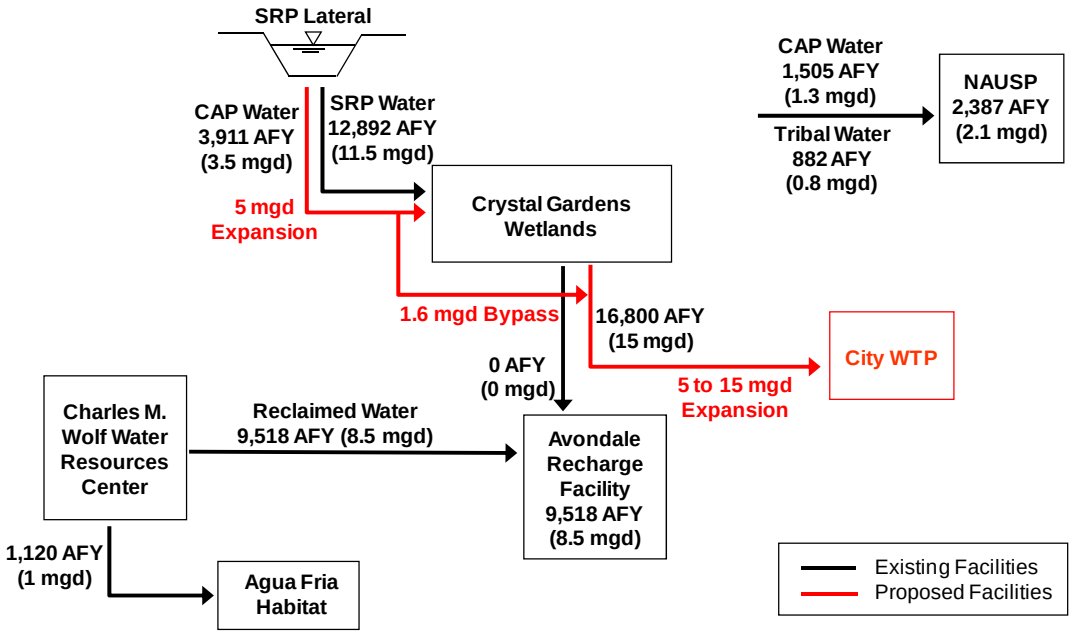


Figure 8-4: Build a Surface WTP: Water Balance

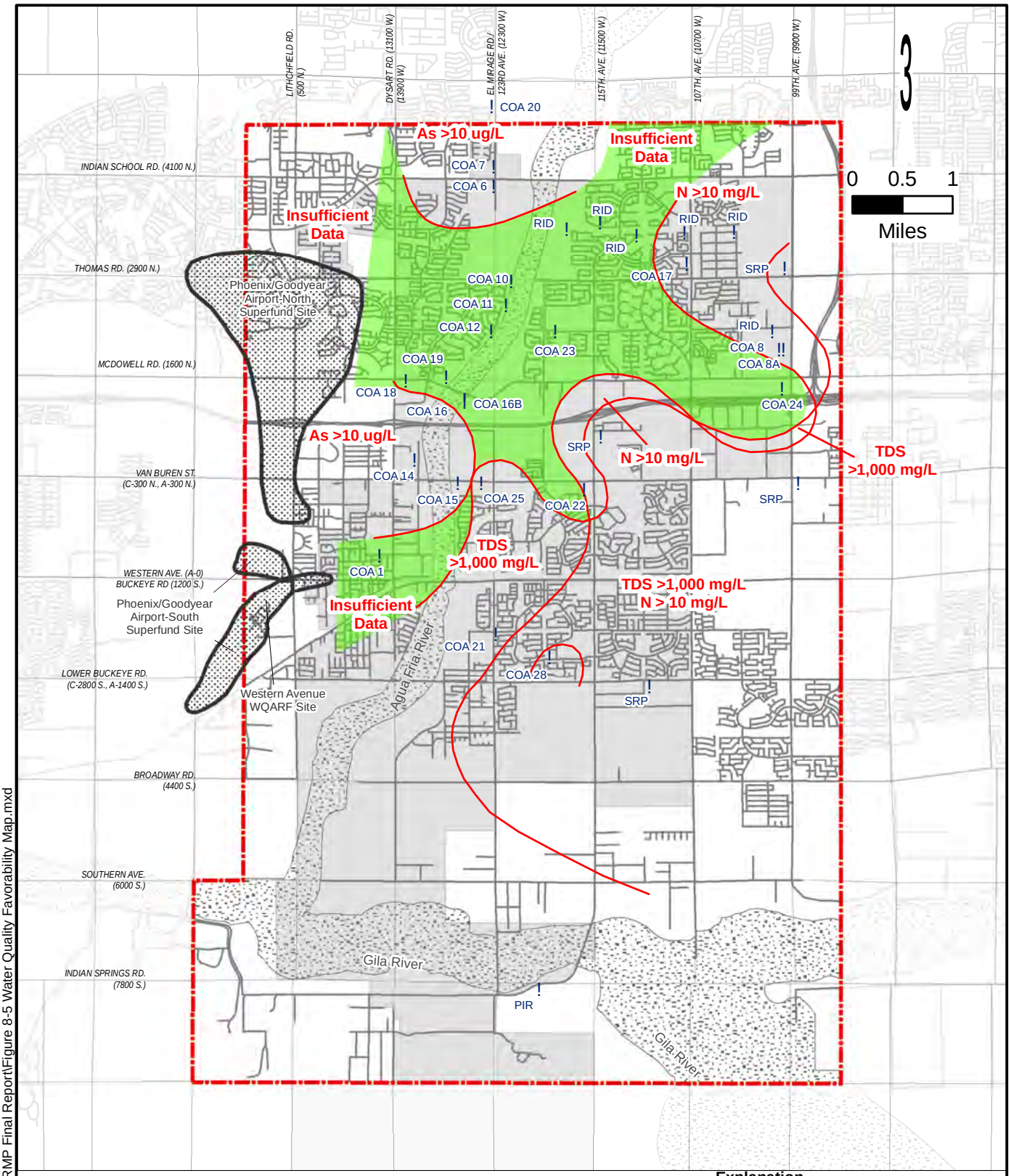
Under the Continue to Build Wells alternatives (Figure 8-3), the City would prioritize reclaimed water recharge at the Avondale Recharge Facility, while maintaining its commitment to maintain the wetlands habitat downstream of the WRF outfall (1,120 AFY). The remaining capacity at the Avondale Recharge Facility would be filled with a portion of SRP water allocations (5,500 AFY). The remaining SRP water (7,400 AFY) would be recharged using the City's share of capacity at the NAUSP. The City's CAP and WMAT lease water would be recharged at CAWCD facilities.

Under the Build a Surface WTP alternatives (Figure 8-4), the City would continue to prioritize reclaimed water recharge at the Avondale Recharge Facility and maintain its commitment to the wetlands habitat. The SRP and a portion of the CAP allocations would be received at Crystal Gardens Wetlands and treated at the surface WTP. Due to capacity restrictions, the City will have to increase the SRP delivery and wetlands effluent capacities to 15 mgd (17,400 AFY). A Crystal Gardens Wetlands bypass would also need to be constructed for an additional 1,800 AFY due to the wetlands hydraulic capacity. The remaining balance of the CAP allocations (1,500 AFY) and the WMAT lease water would be recharged at the NAUSP.

8.2.4. Favorable Groundwater Quality Areas

As part of the hydrogeologic update previously described (Appendix D), groundwater quality was evaluated throughout the study area in order to identify areas where water quality might be more favorable. Water quality considerations included arsenic, nitrate, TDS, fluoride, and dibromochloropropane. Based on the evaluation performed, a favorable water quality map was developed (Figure 8-5).

Under four of the water supply alternatives (Alternatives 1, 2, 4 and 5), it was assumed that all new production wells would be located within the areas of favorable water quality, and that groundwater treatment could be eliminated or minimized through proper well design and construction. Because of the inherent uncertainty in actual groundwater quality that will be encountered; however, additional analyses were evaluated in which certain levels of groundwater treatment were assumed. Water supply Alternative 3 was evaluated to determine the additional groundwater treatment costs that would be incurred if some wells were located within areas of unfavorable groundwater quality, and to see if these costs could be offset by decreased piping and pumping costs due to location of wells closer to demands in the southern portions of the study area.



Superfund Site Programs

WQARF:
Western Avenue Site

Superfund:
Phoenix/Goodyear Airport-North

Phoenix/Goodyear Airport-South

Major Contaminants:
Tetrachloroethene (~60-110 feet below land surface)

Trichloroethene, Perchlorates (~70-130 feet below land surface)

Trichloroethene, Chromium (~0-360 feet below land surface)

Explanation

COA 20 — Water quality data point

Assumed concentration contours:
1000 mg/L total dissolved solids
10 mg/L nitrate
10 ug/L arsenic

Areas with most favorable water quality

Study Area

City of Avondale

CITY OF AVONDALE, ARIZONA
WATER RESOURCE MASTER PLAN

Groundwater Quality Favorability Map

MALCOLM PIRNIE

May 2010

FIGURE 8-5

\\phoenix\projects\0864025\GIS\MXDs\WRMP Final Report\Figure 8-5 Water Quality Favorability Map.mxd

8.2.5. Conceptual Hydraulic Modeling

For the purposes of conceptual sizing of pipelines and pumping requirements, the City's existing water system hydraulic model (calibrated in February 2009) was updated to create a build-out infrastructure model for each alternative. Demands for the build-out year were allocated to the hydraulic models based on demand projections presented in Section 6. The build-out models were evaluated for maximum day and fire flow demand conditions, given the pipe size, pressure, and velocity design criteria described in the 2008 General Engineering Requirements Manual.

8.2.6. New Pressure Zone

The City's water infrastructure is currently contained within one pressure zone. If the City continues to operate its water infrastructure in a single pressure zone, pressures will continually increase as the hydraulic grade from the booster stations has to be increased to satisfy pressure requirements in the southern area. While the build-out system could operate under one pressure zone and meet the pressure design criteria in the south region, some portions of the system in the north will have higher pressures; this configuration may not be the most economical operationally. To alleviate elevated pressures in the northern area and maintain operating pressures throughout the system, a second pressure zone can be delineated south of Lower Buckeye Road.

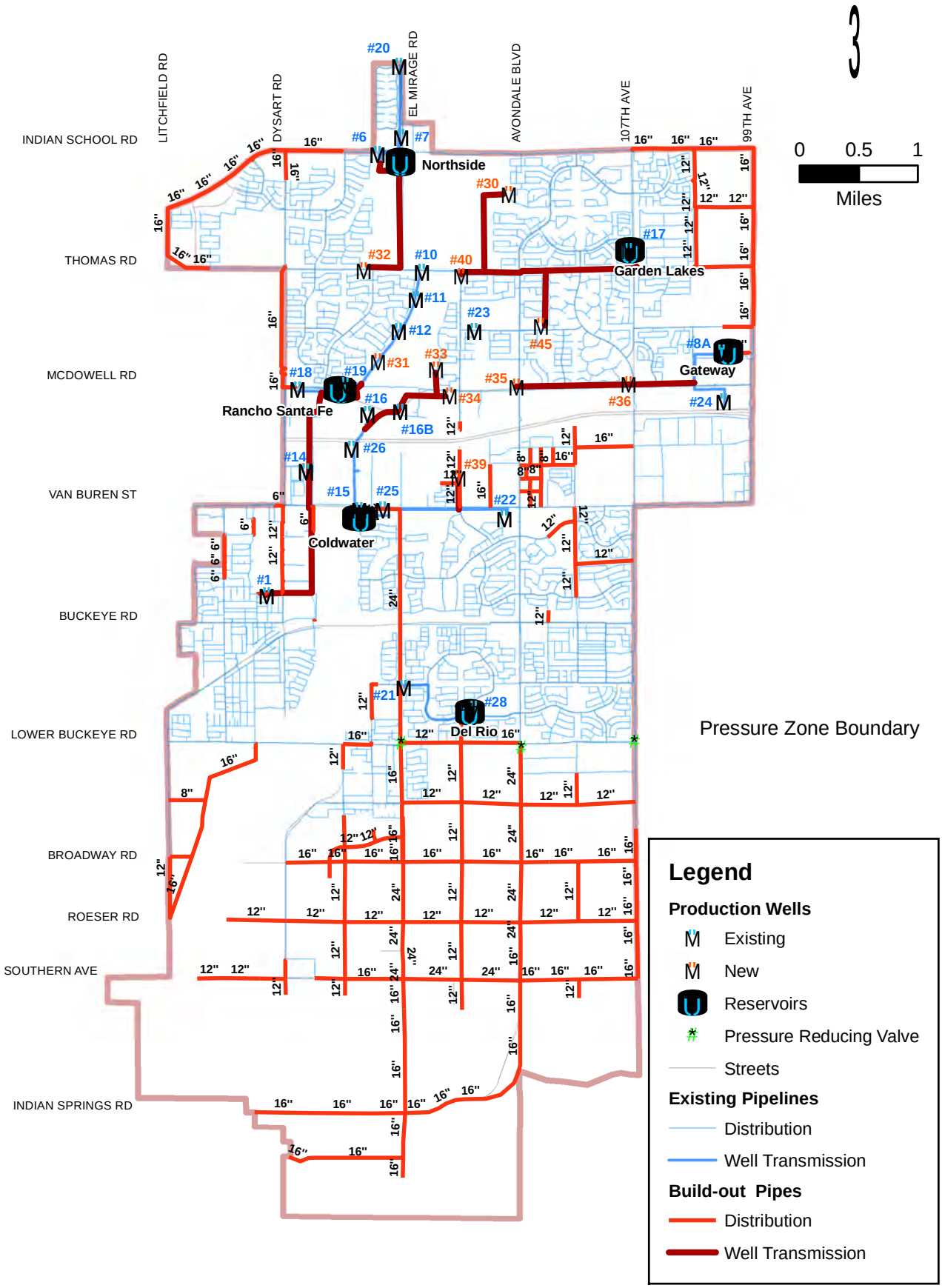
8.3. Development of Alternatives

The five water supply alternatives are described in the following sections, including the major improvements and differences between the alternatives:

8.3.1. Alternative 1: Continue Building Wells (East of Dysart Road)

Under this alternative, as many new wells as possible (according to well spacing requirements) will be located in the northwest portion of the study area and east of Dysart Road. This alternative will assess the potential impacts on the PGA North Superfund Site contamination plume. Figure 8-6 shows the conceptual infrastructure envisioned for Alternative 1, including the following:

- The new infrastructure planned south of Lower Buckeye Road will be included in a new pressure zone. The new pressure zone will be supplied by Coldwater and Del Rio booster stations.
- A dedicated 24-inch line will bring water from the Coldwater booster station to the south pressure zone.
- The north pressure zone will be served by booster stations north of Van Buren Street which includes the Coldwater booster station.
- The pumping capacity at Rancho Santa Fe, Northside, Del Rio, and Garden Lakes booster stations will be increased.



CITY OF AVONDALE, ARIZONA
WATER RESOURCE MASTER PLAN

Alternative 1: Continue Building Wells (East of Dysart Road)

MALCOLM PIRNIE

May 2010

FIGURE 8-6

\\phoenix\projects\0864025\GIS\MXDs\WRMP Final Report\Figure 8-6 Alternative 1.mxd

8.3.2. Alternative 2: Continue Building Wells (Around Avondale Recharge Facility)

Under this alternative the new wells will be placed near the recharge facility to assess the impacts on groundwater mounding and movement if additional pumping is provided within the facility's hydrologic area of impact. Based on well spacing criteria, only two of the new wells used in Alterative 1 could be moved closer to recharge facility in this alternative. The infrastructure requirements for Alternative 2 would remain the same as Alternative 1 as it follows the same pressure zone and pipe layout configurations. Figure 8-7 shows the conceptual infrastructure envisioned for Alternative 2.

8.3.3. Alternative 3: Continue Building Wells (Throughout Service Area)

Under this alternative the location of new wells will be dispersed throughout the study area to improve supply to the water supply facility reservoirs and potentially decrease piping requirements for meeting demands in the south area. Figure 8-8 shows the conceptual infrastructure envisioned for Alternative 3, including the following:

- A separate pressure zone is not needed in the south area.
- Three new wells would be located in unfavorable groundwater quality areas and would provide additional supply to the Del Rio reservoir.
- The pumping capacity at Rancho Santa Fe, Coldwater, and Garden Lakes booster stations would be increased.

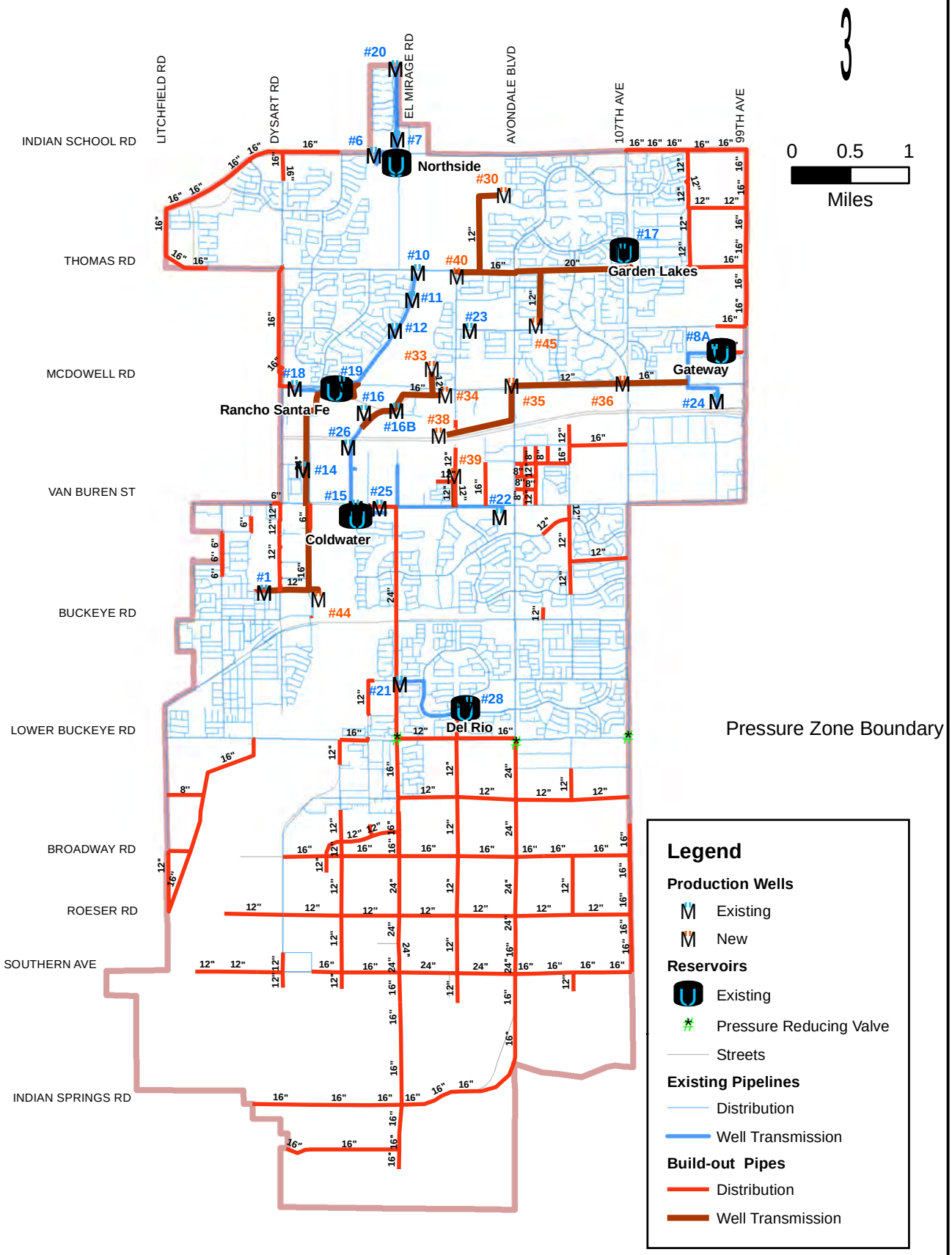
8.3.4. Alternative 4: Build a Surface WTP (At Avondale Recharge Facility)

Under this alternative, a surface WTP will be located on space reserved near the Avondale Recharge Facility. Figure 8-9 shows the conceptual infrastructure envisioned for Alternative 4, including the following:

- A separate pressure zone is not needed in the south area.
- The transmission main from the SRP lateral to the Crystal Gardens Wetlands will have to be upgraded.
- A transmission main would be added from the Crystal Gardens Wetlands to the surface WTP.
- The six new wells required would be located in areas with favorable water quality.
- Pumping capacity at Rancho Santa Fe, Coldwater, and Garden Lakes booster stations would be increased.

8.3.5. Alternative 5: Build a Surface WTP (Near 107th Avenue and Roosevelt Street)

Under this alternative, the surface WTP would be located near the intersection of 107th Avenue and Roosevelt Street, where vacant land is currently available in the industrial area. Figure 8-10 shows the conceptual infrastructure envisioned for Alternative 5 and is



\\phoenix\projects\0864025\GIS\MXDs\WRMP Final Report\Figure 8-7 Alternative 2.mxd

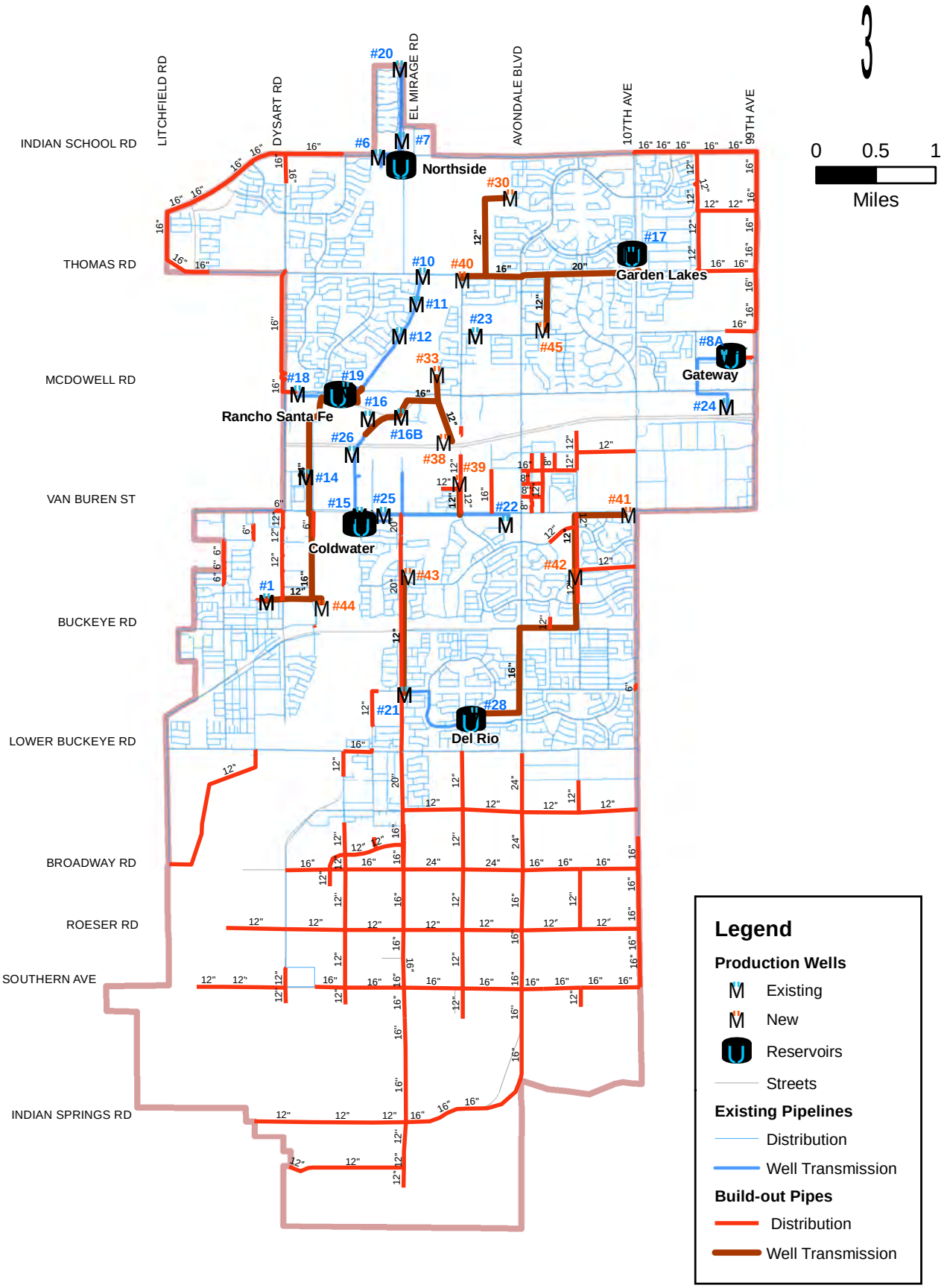
CITY OF AVONDALE, ARIZONA
WATER RESOURCE MASTER PLAN

Alternative 2: Continue Building Wells (Around Avondale Recharge Facility)

MALCOLM PIRNIE

May 2010

FIGURE 8-7



\\phoenix\projects\0864025\GIS\MXDs\WRMP Final Report\Figure 8-8 Alternative 3.mxd

City of Avondale

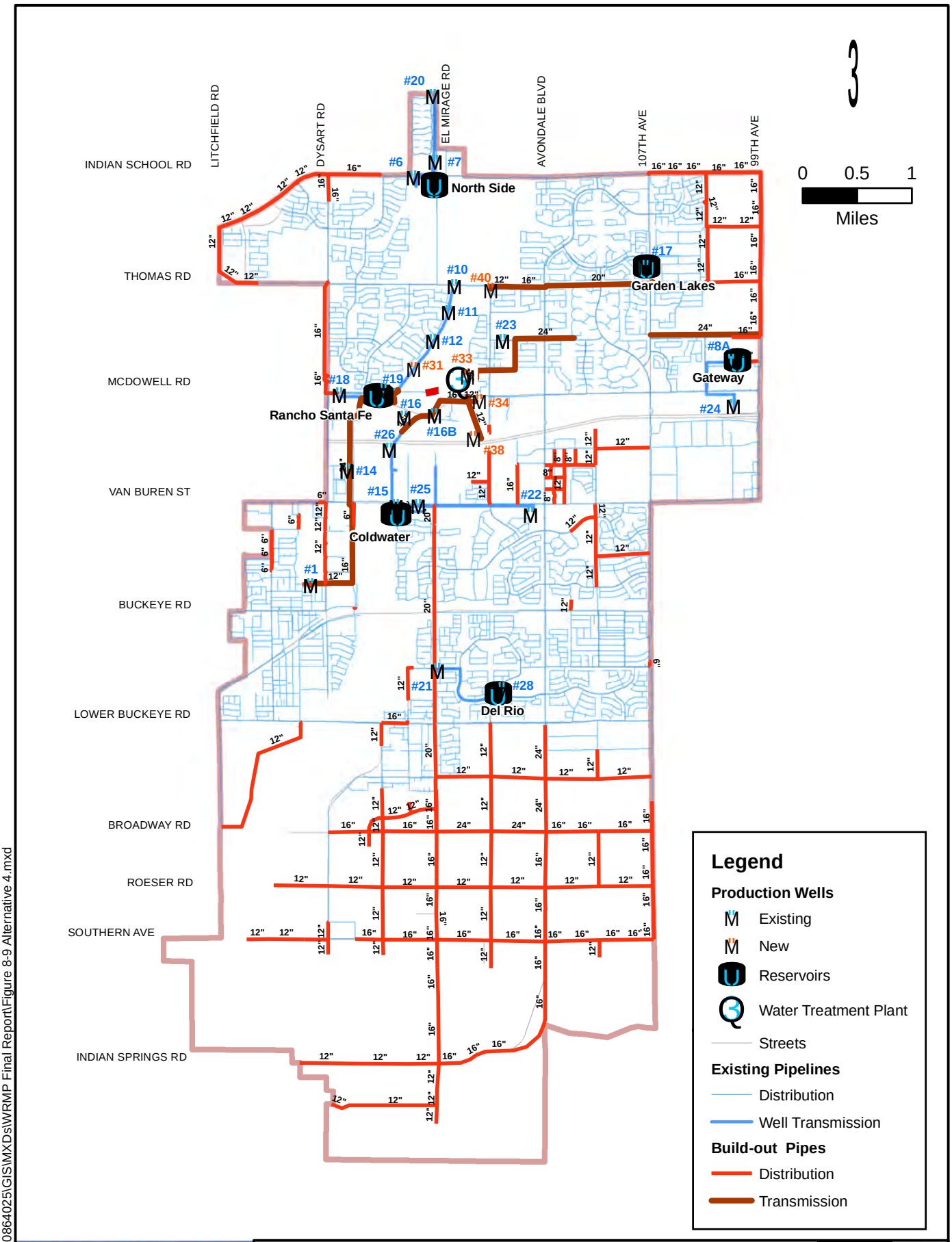
CITY OF AVONDALE, ARIZONA
WATER RESOURCE MASTER PLAN

Alternative 3: Continue Building Wells (Throughout Service Area)

MALCOLM PIRNIE

May 2010

FIGURE 8-8



\\phoenix\projects\0864025\GIS\MXDs\WRMP Final Report\Figure 8-9 Alternative 4.mxd

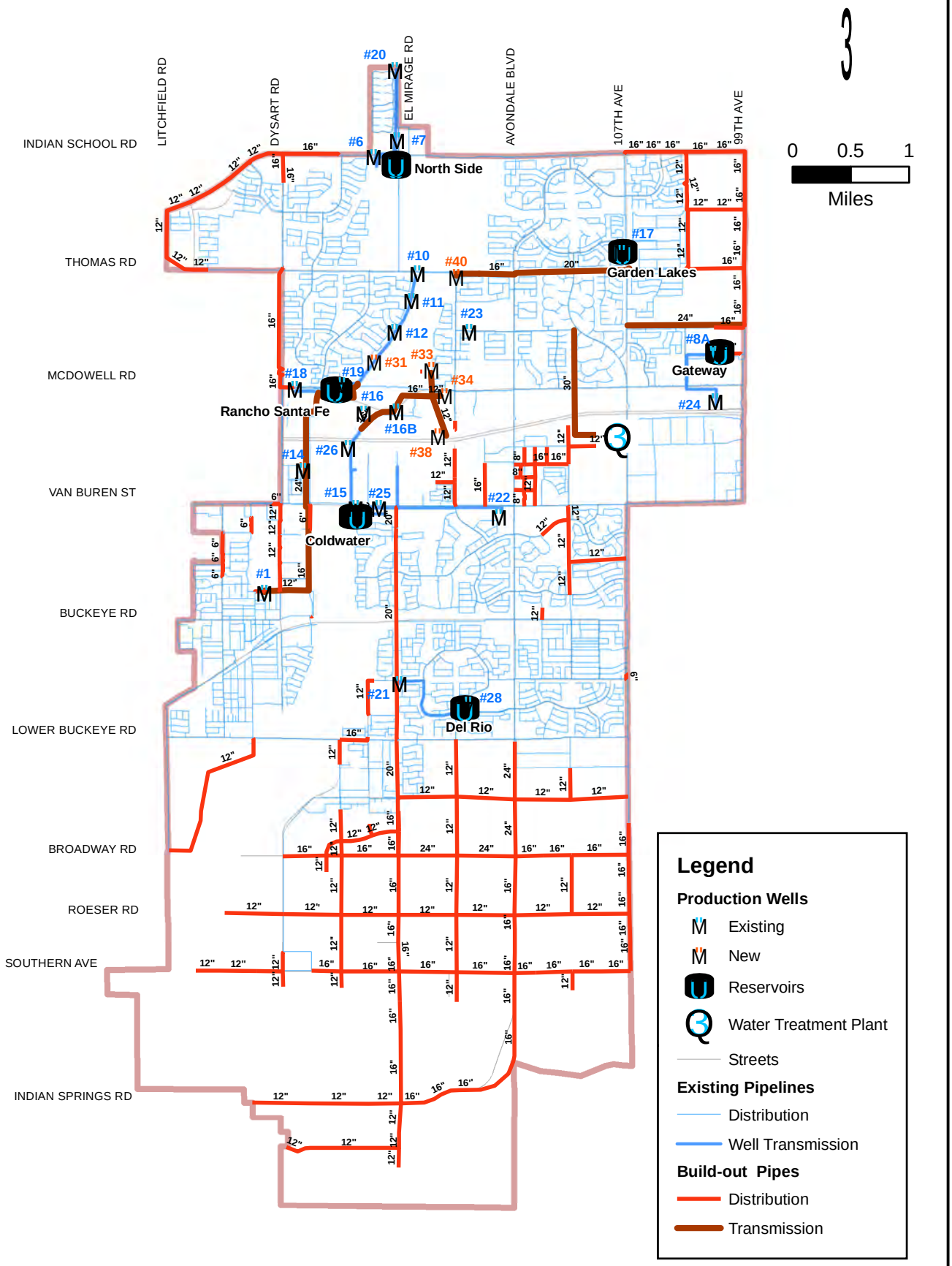
CITY OF AVONDALE, ARIZONA
WATER RESOURCE MASTER PLAN

Alternative 4 : Build a Surface WTP
(At Avondale Recharge Facility)

MALCOLM PIRNIE

May 2010

FIGURE 8-9



\\phoenix\projects\0864025\GIS\MXDs\WRMP Final Report\Figure 8-10 Alternative 5.mxd

CITY OF AVONDALE, ARIZONA
WATER RESOURCE MASTER PLAN

Alternative 5 : Build a Surface WTP
(Near 107th Avenue and Roosevelt Street)

MALCOLM PIRNIE

May 2010

FIGURE 8-10

similar to Alternative 4, except for the transmission main from the Crystal Gardens Wetlands to the surface WTP.

8.4. Hydrogeologic Evaluation of Alternatives

Groundwater modeling was completed for each of the five water supply alternatives to evaluate the impacts of long-term groundwater pumping on the local groundwater table and movement of groundwater.

8.4.1. Groundwater Model

The most current version of ADWR's groundwater flow model for the Salt River Valley (SRV) was used to develop a model for the project study area. For efficiency, only the western portion of ADWR's SRV groundwater flow model was used to develop the Avondale groundwater model. To improve resolution of the model, the ADWR SRV model grid spacing was refined from one-half square mile cells to one-sixteenth of a square mile cells for the study area. Most of the major inputs to the ADWR SRV model remained the same for the Avondale groundwater model. A complete summary of the groundwater model framework, calibration/verification, and simulation of the water supply alternatives is provided in Appendix F.

Once the refined groundwater flow model was fully constructed, the model underwent a calibration/verification process. Since most of the character of the original ADWR model was maintained in the refined model, the calibration/verification process focused on closely reproducing the water budgets from the original groundwater flow model and achieving model errors similar to, or better than, the ADWR model within the refined model domain. The calibration/verification also focused on generally reproducing groundwater flow patterns within the study area.

8.4.2. Summary of Water Supply Alternative Simulations

The five water supply alternatives were simulated for the projected well construction (Section 8.2.2) and pumping to meet projected water demands through build-out within the study area. The simulations also accounted for the projected recharge of reclaimed water and SRP water (Section 8.2.3). The model simulations were made for a 40-year time period, from 2010 to 2050 (the assumed build-out year).

In each of the five water supply alternatives, the maximum simulated groundwater drawdown occurred at build-out. The simulations predict minimal impacts on groundwater levels due to projected pumping of City wells through build-out. The predicted groundwater level drawdown for Alternative 1, 2 and 3 is similar because the location of wells is very similar. Water table drawdown extends across the entire study area with up to 17 feet of drawdown occurring in the northern portion of City's service area, up to nine feet of drawdown at the eastern edge of the study area, eight feet of drawdown at the western edge, and two feet of drawdown at the southern edge.

The effect of constructing a surface WTP in Alternatives 4 and 5 is the reduction of future drawdown in the aquifer due to decreased need for additional groundwater withdrawals. The modeling predicts groundwater elevations at build-out to be similar to current conditions (little to no drawdown) with slight increases around several existing wells that become inactive when the surface WTP is brought on-line. The mounding effect beneath the Avondale Recharge Facility is also predicted to be less due to the decreased volumes of recharged water. In general, the impact to the aquifer will be significantly less for Alternatives 4 and 5 than for Alternatives 1, 2, and 3.

The potential influence of the water supply alternatives on the nearby PGA-North, PGA-South, Western Avenue, and West Van Buren contaminant plumes were also considered for each model simulation. A summary of the predicted drawdown at build-out at these contaminant plumes for the alternatives is summarized in Table 8-1 below. The predicted build-out drawdown at the contaminant plumes under Alternatives 1, 2, and 3 was within one to two feet of each other and the drawdown was also relatively small (less than 10 feet), indicating that the proposed additional groundwater withdrawals will have little influence on the contaminant plumes. The predicted drawdown at the contaminant plumes was less for Alternatives 4 and 5. The decreased reliance on groundwater for Alternatives 4 and 5 results in predicted build-out groundwater elevations that is similar to current elevations or slightly above.

It should be noted that the model simulations did not consider future potential extraction/injection well systems that may be employed to contain and remediate the PGA-North contaminant plume. If these systems are added as is currently being discussed by ADEQ/EPA and the potential responsible parties for the PGA North site, the effect should be to further minimize the potential impacts to the Avondale groundwater wells.

Table 8-1:
Predicted Drawdown at Contaminant Plumes

Alternative	Predicted Drawdown (feet)			
	PGA-North	PGA-South	Western Ave.	West Van Buren[1]
Alt. 1	7-9	6-8	8	5
Alt. 2	6-8	6-8	8-9	5
Alt. 3	6-8	6-8	8-9	5
Alts. 4 and 5	0-(-2)	0	0	-1

Note:
(1) Drawdown at western edge of plume.

8.5. Cost Evaluation of Alternatives

This section describes cost evaluations (capital, operations and maintenance, and total present worth costs) that were developed for each alternative. The objective of the cost evaluations is to provide relative costs for comparing alternatives; the evaluations are not intended for use in capital improvement planning budgets or setting rates.

Capital and operations and maintenance (O&M) cost estimates were developed for the build-out required system improvements and upgrades identified for each water supply alternative. The cost estimates presented are based on available existing studies, recent projects with similar components, manufacturer's budget estimates, 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 International. This level of engineering cost estimating is approximate and generally made without detailed engineering data and site layouts, but is appropriate for preliminary budget-level estimating. The accuracy range 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.

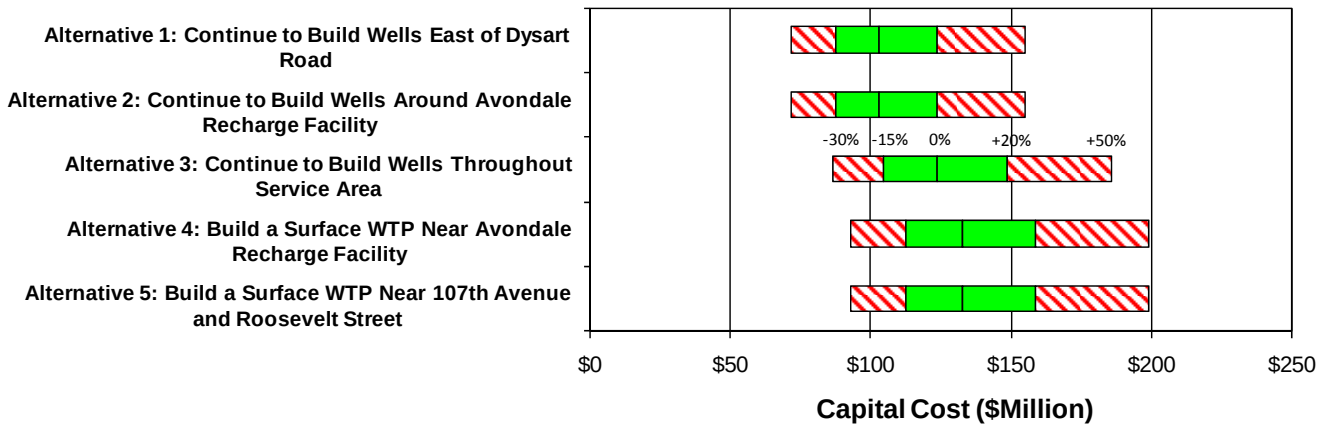
Appendix E contains unit cost information and other assumptions used in this project for construction and O&M of the infrastructure. The unit capital costs include materials of construction, installation, and contractor costs (overhead, profit, bonding, mobilization). All costs include a 20 percent factor for engineering and construction administration and 30 percent for project contingencies. The unit O&M costs include labor, power, chemicals, maintenance, and materials. All costs are in November 2009 dollars referenced to an Engineering News Record Construction Cost Index (ENR CCI) of 8,592.

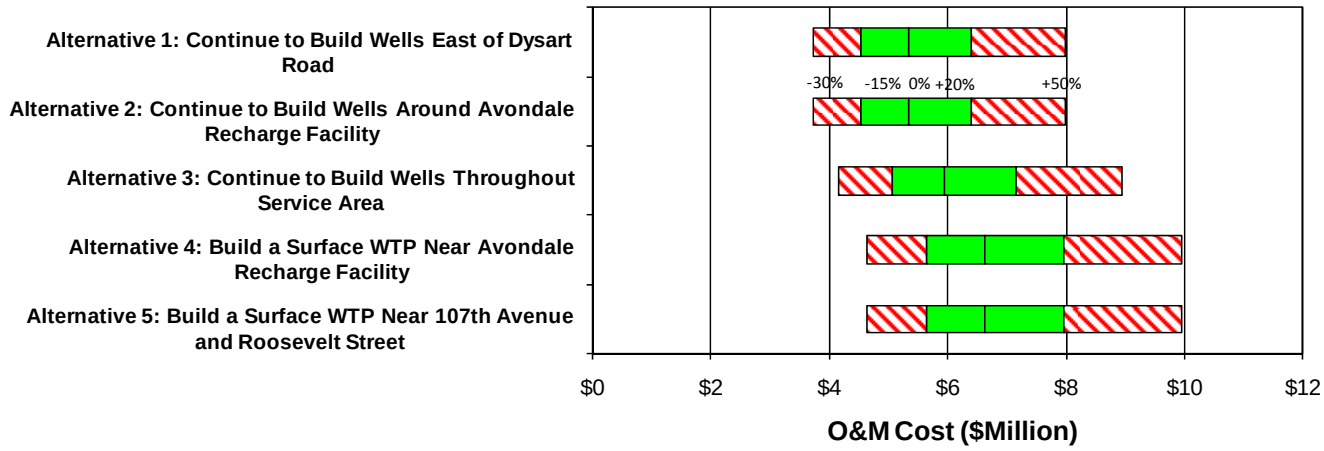
The relative economic feasibility of the alternatives was compared based on an equivalent present worth cost basis. The equivalent present worth cost for each alternative is the sum of total capital cost plus the estimated annual O&M cost, summed over a 20-year study period at an interest rate of six percent. A summary of the costs determined for each of the five alternatives is presented in Table 8-2 and is shown graphically on Figure 8-11. Appendix E also contains the detailed cost calculations for each alternative.

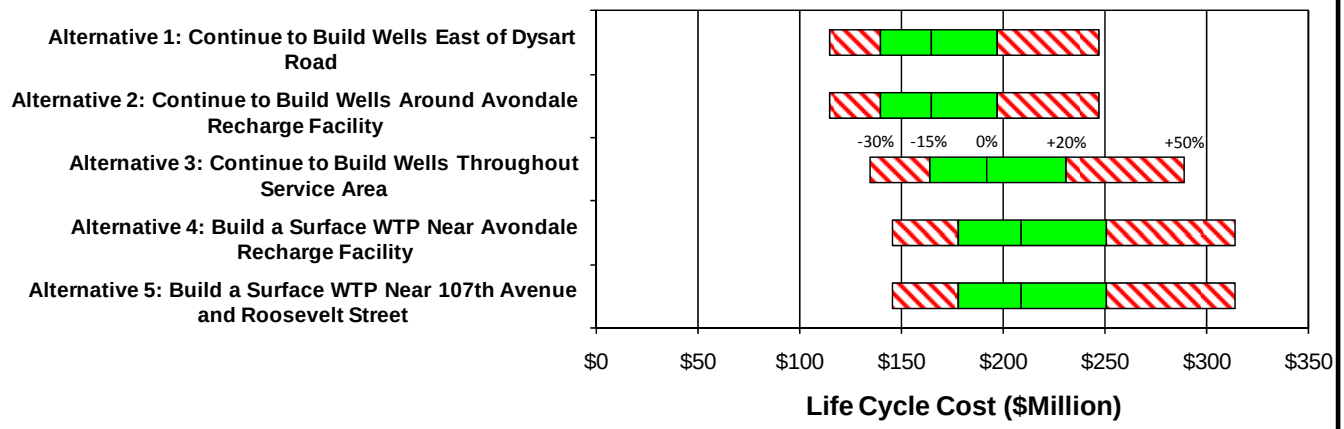
Table 8-2:
Cost Comparison of Water Supply Alternatives

	Alt. 1	Alt. 2	Alt. 3	Alt. 4	Alt. 5
Capital Cost ($M)	$103.3 M	$103.3 M	$124.0 M	$132.8 M	$132.8 M
Annual O&M Cost ($M/year)	$5.3 M	$5.3 M	$6.0 M	$6.6 M	$6.6 M
Present Worth O&M Cost ($M)	$61.2 M	$61.2 M	$68.4 M	$76.2 M	$76.2 M
Total Present Worth ($M)	**$164.5 M**	**$164.5 M**	**$192.4 M**	**$209.0 M**	**$209.0 M**

Notes:
(1) November 2009 Costs (ENR CCI = 8,592).
(2) 20 years, 6 percent interest.







Costs assume that all new wells located in favorable water quality areas do not require treatment.

CITY OF AVONDALE, ARIZONA
WATER RESOURCE MASTER PLAN

Cost Comparison of Water Supply Alternatives (No Additional Groundwater Treatment)

May 2010

Figure 8-11

Water Supply Alternatives 1 and 2 had the lowest total present worth cost ($165 M). Alternative 3 total present worth costs were approximately $28 M higher than Alternatives 1 and 2 because of increased groundwater treatment. Alternatives 4 and 5 were the highest cost alternatives with a total present worth cost of $209 M.

With the exception of Alternative 3, all new groundwater wells were assumed to be located in areas with favorable water quality, shown previously on Figure 8-5. A sensitivity analysis (also included in Appendix E) was performed to evaluate the effect of additional groundwater treatment on the overall cost evaluation of water supply alternatives. The analysis considered two levels of additional groundwater treatment. First, it was assumed that 25 percent of the groundwater would be treated on a volume basis. Based on City production records, this is the approximate percentage of groundwater that was treated in 2008 by volume. Second, it was assumed that 75 percent of future wells would require treatment based on the fact that 75 percent of existing wells currently require treatment to operate. The treatment was assumed to be for arsenic, nitrate, or both. Figures 8-12 and 8-13 present the cost comparisons for the water supply alternatives under the increasing levels of groundwater treatment assumed. The sensitivity analyses indicate an overall increase in costs; however, the relative cost rankings were not affected.

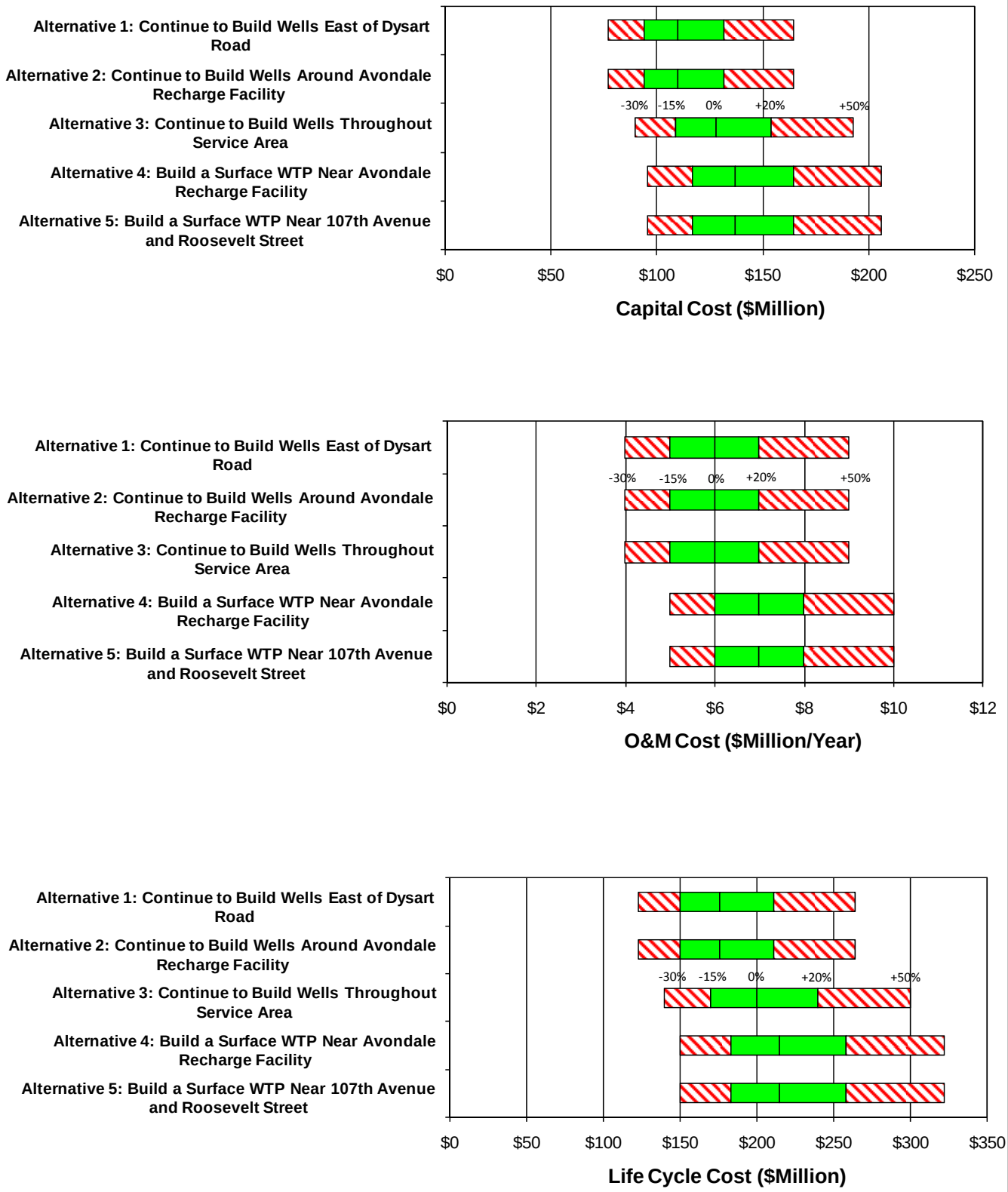
8.6. Matrix Evaluation of Alternatives

The five water supply alternatives were further compared using a matrix comparison to identify the preferred water supply strategy. The matrix comparison was based on criteria that are important to a decision on a future water supply strategy. The comparison was accomplished by a systematic weighting and scoring of the decision criteria for each alternative. The identification of decision criteria and matrix evaluation were completed during workshops with the City project team.

8.6.1. Decision Criteria

During a workshop, the City staff was asked to discuss and identify decision criteria that are important to selecting a preferred water supply strategy. The decision criteria developed by the City are described below:

- **Life Cycle Costs -** The total life cycle costs of an alternative, including capital costs and 20 years of annual O&M costs, discounted at 6 percent interest. Alternatives with lower life cycle costs are more preferable.
- **Annual O&M Costs -** The total annual O&M cost for each alternative, including labor, materials, chemicals, and equipment maintenance and replacement. Alternatives with lower annual O&M costs are more preferable.
- **Financial Capacity -** Magnitude and timing of capital expenditures that could stress the City's funding capacity. Alternatives that have lower and more distributed capital requirements would be more preferable.



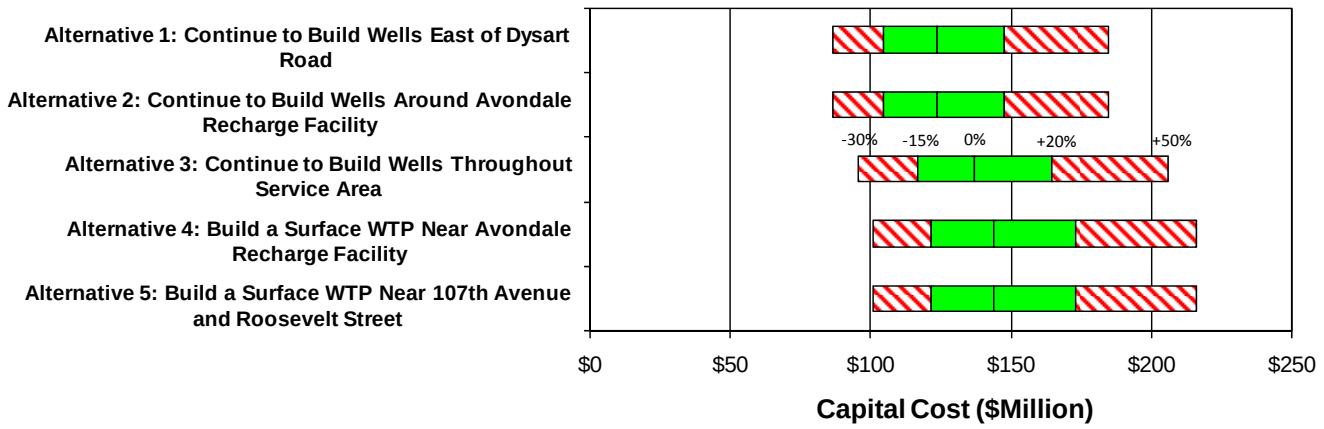
Costs assume that 25 percent of all new wells located in favorable water quality areas require treatment some form of treatment.

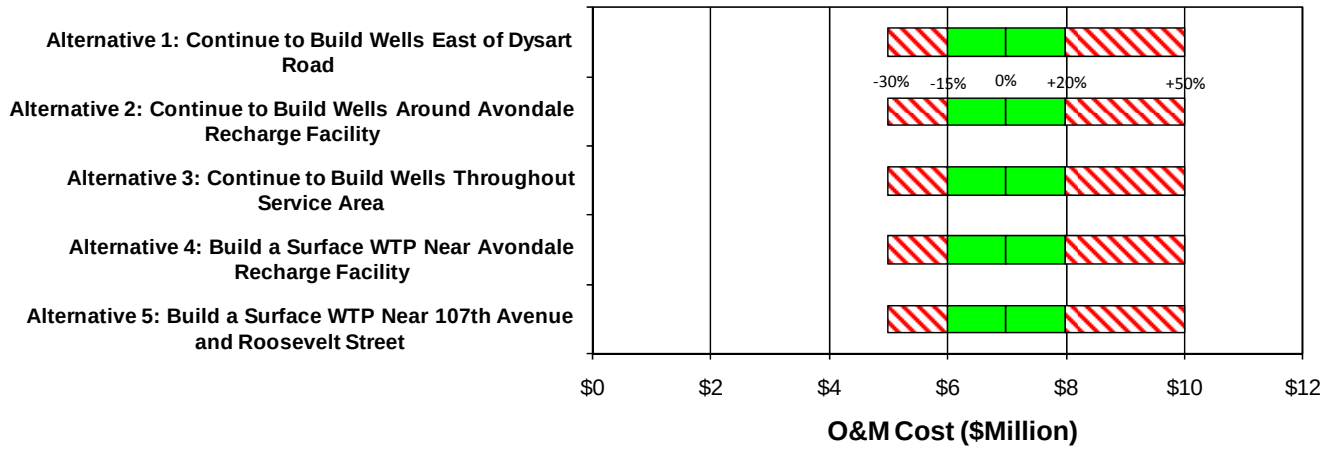
CITY OF AVONDALE, ARIZONA
WATER RESOURCE MASTER PLAN

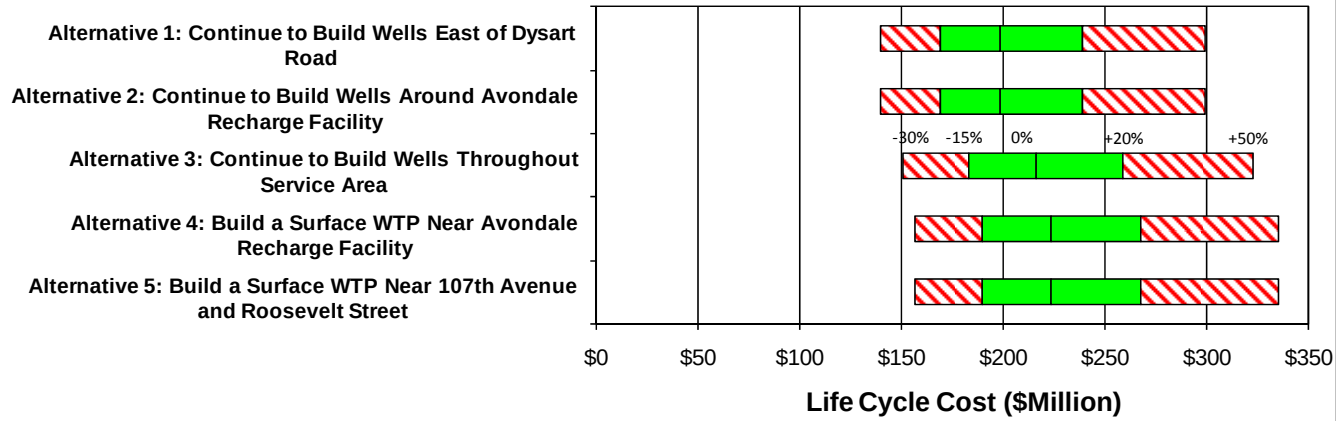
Cost Comparison of Water Supply Alternatives (25 Percent Groundwater Treatment by Volume)

May 2010

Figure 8-12







Costs assume that 75 percent of all new wells located in favorable water quality areas require treatment some form of treatment.

CITY OF AVONDALE, ARIZONA
WATER RESOURCE MASTER PLAN

Cost Comparison of Water Supply Alternatives (75 Percent Groundwater Treatment by Volume)

May 2010

Figure 8-13

- **Source Water Reliability -** The susceptibility of the source water supply to shortages (drought) and supply interruptions (canal outages), impacting the PGA North Superfund Site contaminant plume, and potential to sustain aquifer levels (and recharge capacity). Alternatives with more reliable source water supplies, less potential to impact contaminant plumes, and that would better sustain local groundwater levels are more preferable.
- **Water Quality Management -** The ability and flexibility to manage service area-wide water quality given source water quality (TDS, arsenic, nitrate), source water quality variations, and potential for contaminant formation (disinfection by-products in surface water). This criterion also includes the ability to adapt to future water quality regulations. Alternatives with more stable source waters, more flexible and less complex operations to meet water quality standards, and better ability to adapt to future water treatment requirements are more preferable.
- **Operational Requirements -** Complexity of facility operations and need for operator attention. Alternatives with fewer and less complex facilities to operate, requiring lower staffing requirements, are more preferable.
- **Institutional/Legal -** Complexity of implementation, including number and complexity of required agency approvals and support, potential for regulatory scrutiny (superfund site impacts), necessary agreements, water exchanges, and permits, and future regulatory policies. Alternatives that are less susceptible to regulatory and institutional scrutiny and require fewer and less complex permits or approvals are more preferable.
- **Carbon Footprint -** The total estimated greenhouse gases (carbon dioxide) generated due to operational water pumping (power) and chemical production. Alternatives with lower carbon dioxide emissions are more preferable.
- **Public Perception -** The potential to generate negative public sentiment due to water quality changes (groundwater vs. surface water, taste and odor), neighborhood impacts (O&M traffic, presence of chemicals), and water rate impacts. Alternatives that should generate less public scrutiny due to water quality concerns, less neighborhood impacts, and less potential for rate increases are more preferable.

8.6.2. Decision Criteria Prioritization

The next step of the matrix evaluation was to determine the City's prioritization for the decision criteria. The weighting, or assigning of relative importance between the criteria, was determined in a workshop using a pair-wise comparison methodology. In this methodology, every criterion is compared against all the other criteria to determine the priority or degree of importance of each criterion relative to the other criteria.

In the workshop, each City participant in the group was asked to compare each criterion against all other criteria, individually, to determine 1) which criterion was more important, and 2) by how much. A commercially available software program called Criterium Decision Plus was used to assist in the weighting of the decision criteria. After

each criterion was compared against all other criteria, the software calculated the resulting relative importance of each criterion.

Figure 8-14 illustrates the resulting decision criteria priorities, or weights, calculated by averaging each participant's score together. *Financial capacity* was identified as the most important criterion with 23 percent weight. The next most important decision criteria were *institutional/legal complexity* (19 percent weight), *source water reliability* (16 percent weight), *life cycle costs* (13 percent weight), and *water quality management* (11 percent weight). The remaining four criteria (*annual O&M costs*, *public perception*, *operational requirements*, and *carbon footprint*) were weighted at 6 percent weight and less.

8.6.3. Alternative Scoring

The next step of the matrix evaluation process was to score each alternative based on the alternatives' attributes under each criterion. Table 8-3 summarizes the scoring of decision criteria for each alternative and includes the criteria, the attributes of each alternative under each criterion, and the score assigned to each alternative under each criterion based on the attributes. Scores between 1 and 5 were assigned, with 1 being least favorable to 5 being most favorable.

8.6.4. Alternative Rankings

The final step of the matrix evaluation process was to determine the total weighted scores for the alternatives. This was accomplished by taking the sum of the criteria scores for each alternative presented in Table 8-3 and multiplying them by the weighting factors. Figure 8-15 presents the results of the weighted scores and ranking of the reclaimed water program alternatives. The rankings lead to the following conclusions:

- Continuing to build wells by locating production wells in areas with favorable water quality (Alternatives 1 and 2) is most preferable.
- Continuing to build wells by locating some production wells south of Van Buren Street and north of Buckeye Road (Alternative 3), where production wells may require some form of treatment (arsenic or nitrate), is next most preferable.
- Constructing a surface WTP (Alternatives 4 and 5) was the least preferred.

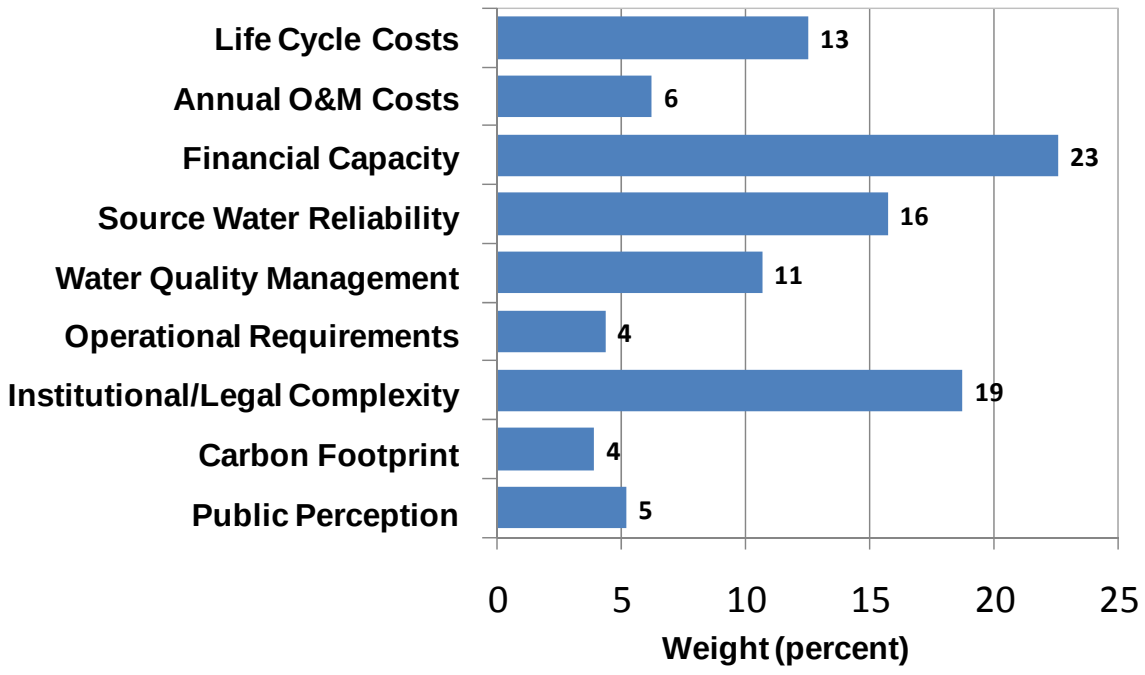


Figure 8-14: Decision Criteria Weights

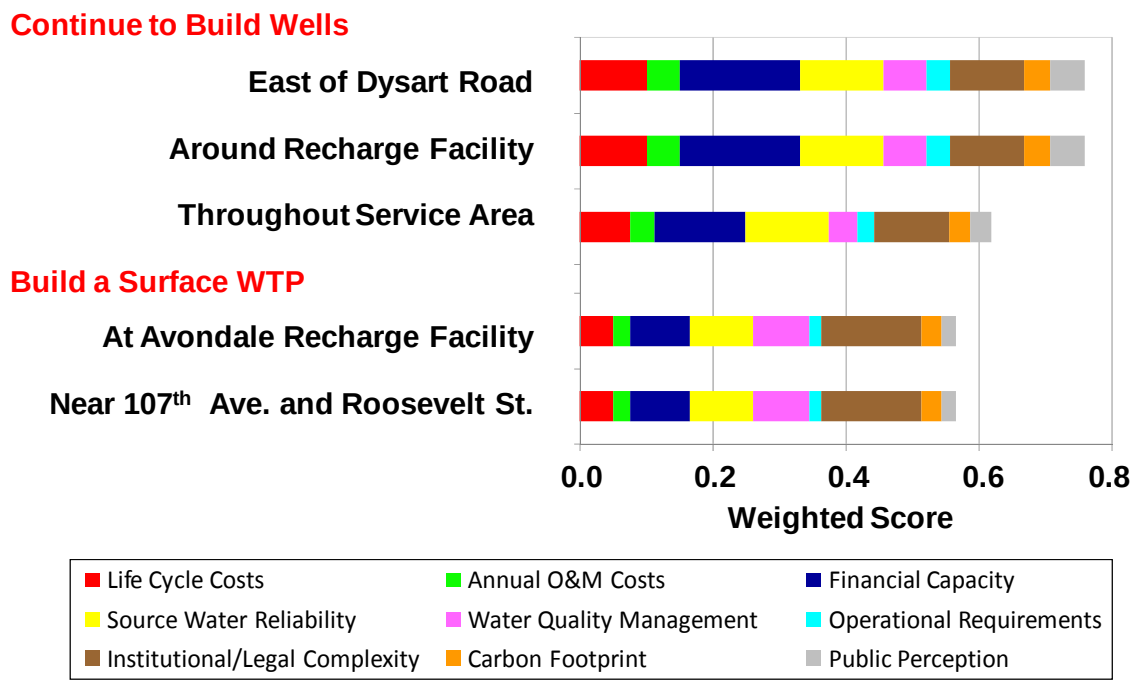


Figure 8-15: Ranking of Water Supply Alternatives

8.7. Selected Future Water Supply Alternative

The following is a brief summary of the significant findings resulting from the evaluation of water supply alternatives:

- The estimated life cycle costs for the Continue to Build Wells alternatives will be 20 percent less than the Build a Surface WTP alternatives.
- The cost evaluations are sensitive to the need for future groundwater treatment for arsenic, nitrates, TDS and other constituents that are known to be present in the City's groundwater supplies. The conclusion above assumes that future wells could be located and constructed to minimize or avoid groundwater treatment. When a reasonable upper level of additional groundwater treatment is considered, the life cycle costs for the Continue to Build Wells alternatives are 10 percent less than the Build a Surface WTP alternatives.
- The groundwater modeling indicates that the impacts of the City's future groundwater pumping will be relatively minor, amounting to generally less than 17 feet of additional water level drawdown through build-out and minimal changes in groundwater flow directions.
- The weighting and ranking of decision factors important to selecting a future water supply strategy indicate that the Continue to Build Wells alternatives are preferred over the Build a Surface WTP alternatives.

Based on evaluations, the Continue to Build Wells strategy (Alternatives 1, 2 and 3) is the preferred future water supply strategy. As Alternatives 1 and 2 are similar and lower in costs than Alternative 3, the remainder of the Water Resource Master Plan update and finalization of the companion Water Infrastructure Master Plan update is based on these alternatives. Although the Continue to Build Wells strategy was preferred, the City should preserve the option to build a surface WTP in the future. A surface WTP may provide benefits in achieving future assured water supply designations and could alleviate the need to build additional recharge capacity; and, could minimize the need for costly groundwater treatment. At a minimum, the City should lock up a site now for a potential surface WTP while available land still exists.

As indicated at the beginning of this section, the above evaluations were based on preliminary information, including existing well capacities, production and storage requirements, etc., and were conducted to identify a preferred water supply strategy. The selected strategy was further defined and refined to develop the recommended Water Infrastructure Master Plan update. Thus the information presented in this section and Appendices E and F may not match the refined information in the Water Infrastructure Master Plan update.

Table 8-3:
Alternative Decision Criteria Scoring

Criteria	Continue to Build Wells East of Dysart Road		Continue to Build Wells Around Avondale Recharge Facility		Continue to Build Wells Throughout Service Area		Build a Surface WTP At Avondale Recharge Facility		Build a Surface WTP Near 107th Avenue and Roosevelt Street	
	Attributes	Score	Attributes	Score	Attributes	Score	Attributes	Score	Attributes	Score
Life Cycle Costs: Capital costs and 20 years of annual O&M, discounted.	$164.5 M	4	$164.5 M	4	$192.4 M	3	$209 M	2	$209 M	2
Annual O&M Costs: Total annual costs for labor, materials, chemicals, and equipment replacement.	$5.3 M	4	$5.3 M	4	$6.0 M	3	$6.6 M	2	$6.6 M	2
Financial Capacity: Magnitude and timing of capital expenditures that would stress the City's funding capacity.	+ Capital costs are distributed over time	4	+ Capital costs are distributed over time	4	+ Capital costs are distributed over time - Additional groundwater treatment requires higher capital expenditures	3	-- $31 million WTP capital expenditure in 2020, additional $15 million in 2025 + Time available for CIP planning	2	-- $31 million WTP capital expenditure in 2020, additional $15 million in 2025 + Time available for CIP planning	2
Source Water Reliability: Susceptibility of source water supply to shortages and supply interruptions, impacting the PGA contaminant plume, and potential to sustain aquifer levels (and recharge capacity).	++ Groundwater has greatest resistance to shortages (as long as it is regularly replenished) + Flexibility of multiple wells + Additional groundwater pumping results in minimal additional drawdown and does not noticeably change groundwater flow directions + 15,000 AFY locally recharged	4	++ Groundwater has greatest resistance to shortages (as long as it is regularly replenished) + Flexibility of multiple wells + Additional groundwater pumping results in minimal additional drawdown and does not noticeably change groundwater flow directions + 15,000 AFY locally recharged	4	++ Groundwater has greatest resistance to shortages (as long as it is regularly replenished) + Flexibility of multiple wells + Additional groundwater pumping results in minimal additional drawdown and does not noticeably change groundwater flow directions + 15,000 AFY locally recharged	4	-- Surface water is more susceptible to shortage (up to 15 mgd) + SRP water can be groundwater which is less susceptible to shortages (as long as it is regularly replenished) - Less flexibility, up to 15 mgd from one source ++ Replacing groundwater pumping with surface water potentially can greatly reduce additional drawdown + Additional groundwater pumping does not noticeably change groundwater flow directions, potential to inactivate northern wells could shift groundwater flows more northerly - 9,500 AFY locally recharged	3	-- Surface water is more susceptible to shortage (up to 15 mgd) + SRP water can be groundwater which is less susceptible to shortages (as long as it is regularly replenished) - Less flexibility, up to 15 mgd from one source ++ Replacing groundwater pumping with surface water potentially can greatly reduce additional drawdown + Additional groundwater pumping does not noticeably change groundwater flow directions, potential to inactivate northern wells could shift groundwater flows more northerly - 9,500 AFY locally recharged	3

Table 8-3:
Alternative Decision Criteria Scoring (cont.)

Criteria	Continue to Build Wells East of Dysart Road		Continue to Build Wells Around Avondale Recharge Facility		Continue to Build Wells Throughout Service Area		Build a Surface WTP At Avondale Recharge Facility		Build a Surface WTP Near 107th Avenue and Roosevelt Street	
	Attributes	Score	Attributes	Score	Attributes	Score	Attributes	Score	Attributes	Score
Water Quality Management: Ability and flexibility to manage service area water quality given source water quality, quality variations, and potential for contaminant formation. Also, ability to adapt to future regulations.	-- Susceptible to groundwater contaminants (TDS, nitrates, arsenic, DBCP) + Wells located in areas of favorable water quality + Less water quality variability + All groundwater, less DBP potential - Treatment technologies are contaminant specific - Greater site constraints (future treatment)	3	-- Susceptible to groundwater contaminants (TDS, nitrates, arsenic, DBCP) + Wells located in areas of favorable water quality + Less water quality variability + All groundwater, less DBP potential - Treatment technologies are contaminant specific - Greater site constraints (future treatment)	3	-- Susceptible to groundwater contaminants (TDS, nitrates, arsenic, DBCP) - 3 wells located in areas of less favorable water quality + Less water quality variability + All groundwater, less DBP potential - Treatment technologies are contaminant specific - Greater site constraints (future treatment) - Brine management for TDS treatment	2	+ Less susceptible (up to 15 mgd) to groundwater contaminants (TDS, nitrates, arsenic, DBCP) -- Higher source water quality variability - Surface water, greater DBP potential - Corrosion concerns when introducing surface water to distribution system + Up to 15 mgd treated surface water available for blending ++ WTP offers broad-based treatment + Site can be master planned for future quality regulations	4	+ Less susceptible (up to 15 mgd) to groundwater contaminants (TDS, nitrates, arsenic, DBCP) -- Higher source water quality variability - Surface water, greater DBP potential - Corrosion concerns when introducing surface water to distribution system + Up to 15 mgd treated surface water available for blending ++ WTP offers broad-based treatment + Site can be master planned for future quality regulations	4
Operational Requirements: Complexity of facility operations and need for operator attention.	- Most groundwater facilities to operate (34 wells, 6 storage/pumping) - Potential for multiple treatment facilities with different treatment technologies	4	- Most groundwater facilities to operate (34 wells, 6 storage/pumping) - Potential for multiple treatment facilities with different treatment technologies	4	- Most groundwater facilities to operate (34 wells, 6 storage/pumping) -- Greater potential for multiple treatment facilities with different treatment technologies	3	+ Fewer groundwater facilities to operate (29 wells, 6 storage/pumping) - WTP requires increase in operation staff - WTP requires higher operator certification	2	+ Fewer groundwater facilities to operate (29 wells, 6 storage/pumping) - WTP requires increase in operation staff - WTP requires higher operator certification	2
Institutional/Legal: Number and complexity of required other agency approvals and support, potential for regulatory scrutiny, agreements, water exchanges, and permits.	++ Least complex, status quo - Greatest number of wells (13) to permit - CAWCD recharge not annually guaranteed (6,300 AFY) - CAP water not recharged locally	3	++ Least complex, status quo - Greatest number of wells (13) to permit - CAWCD recharge not annually guaranteed (6,300 AFY) - CAP water not recharged locally	3	++ Least complex, status quo - Greatest number of wells (13) to permit - CAWCD recharge not annually guaranteed (6,300 AFY) - CAP water not recharged locally	3	- Coordination is needed with SRP + Status quo for source water deliveries + Fewer wells (8) to permit + Need for CAWCD recharge can be reduced	4	- Coordination is needed with SRP + Status quo for source water deliveries + Fewer wells (8) to permit + Need for CAWCD recharge can be reduced	4
Carbon Footprint: Estimated greenhouse gases generated due to operational water pumping and chemical production.	+ Minimal chemical use and chlorination + Estimated energy use less than surface WTP = Estimated carbon emissions are 8,000 MT CO_2/year ($160K/year)	5	+ Minimal chemical use and chlorination + Estimated energy use less than surface WTP = Estimated carbon emissions are 8,000 MT CO_2/year ($160K/year)	5	+ Minimal chemical use and chlorination + Estimated energy use less than surface WTP = Estimated carbon emissions are >8,000 MT CO_2/year ($160K/year)	4	- Additional chlorine and chemicals (alum) needed for treatment - Estimated energy use more than groundwater pumping = Estimated carbon emissions are 11,000 MT CO_2/year ($220K/year)	4	- Additional chlorine and chemicals (alum) needed for treatment - Estimated energy use more than groundwater pumping = Estimated carbon emissions are 11,000 MT CO_2/year ($220K/year)	4
Public Perception: Potential for negative public sentiment due to water quality changes, neighborhood impacts, and water rate impacts.	+ No change in source water + Public used to groundwater facilities in neighborhoods + Lower potential for rate impacts from increased groundwater treatment	5	+ No change in source water + Public used to groundwater facilities in neighborhoods + Lower potential for rate impacts from increased groundwater treatment	5	+ No change in source water + Public used to groundwater facilities in neighborhoods - Greater potential for rate impacts from increased groundwater treatment	3	- Change (up to 15 mgd) in source water - More traffic near WTP - Greatest potential for water rate increasess	2	- Change (up to 15 mgd) in source water - More traffic near WTP - Greatest potential for water rate increasess	2

9. Conclusions and Recommendations

This section summarizes the significant findings and conclusions regarding future water supply strategies to support projected City growth. The section also provides recommendations to achieve and maintain assured water supply status with the ADWR and to maintain an adequate, secure, reliable water supply in the future.

All of the findings, conclusions, and recommendations are made with respect to the study area, which includes the City's MPA north of the Estrella Mountains, including the PIR and its surrounding developments and the service area of the Rigby Water Company.

9.1. Significant Findings and Conclusions

The following significant findings and conclusions result from the information collected and analyzed and the evaluations conducted in this Water Resource Master Plan update:

9.1.1. Water Demands

- Water demands within SRP On-Project lands are projected to increase from 7,300 AFY (6.5 mgd) currently to 12,900 AFY (11.5 mgd) at build-out of On-Project Areas.
- Water demands in SRP Off-Project Areas are projected to increase from 7,200 AFY (6.4 mgd) currently to 16,700 AFY (14.9 mgd) at build-out.
- The total study area demands are projected to increase from 14,500 AFY (12.9 mgd) currently to 29,600 AFY (26.4 mgd) at build-out.

9.1.2. Existing Water Supplies

- The City's existing designation of assured water supply includes a total supply of 28,090 AFY, consisting of SRP entitlement water, CAP subcontract water, and groundwater through groundwater allowances, incidental recharge, and membership in the CAGRD. The SRP entitlement of 8,463 AFY will grow as member lands develop and are cut over to the City and can only be used On-Project and only up to the actual demand of SRP member lands.
- On October 10, 2008, the City complied with requirements to submit an Application for Modification of its Designation of Assured Water Supply. A decision by ADWR regarding this application has not been formally transmitted to the City. The City's existing designation is considered in effect until a final determination based upon the current application is issued by ADWR. The Application for Modification of Designation of Assured Water Supply demonstrates that sufficient renewable supplies are available to the City to accommodate future growth, as planned, without depending on excess groundwater (groundwater to be replenished by the CAGRD).

9.1.3. Future Water Supplies

- Long-term renewable water supplies currently available to the Phoenix AMA have essentially been fully allocated (with the possible exception of Non-Indian Agricultural CAP water). The next large blocks of water supply for the region are believed to be brackish groundwater from the southwest valley area, the Lower Colorado River area, and/or desalinated seawater, perhaps from as far away as Mexico. The development of these additional supplies will be too challenging, lengthy, and expensive for a single entity (like Avondale) to achieve on its own. Likely, a regional water agency (such as the CAWCD, Bureau of Reclamation, etc.) will implement the potential new supplies with the coordination, participation, and for the benefit of all communities in the region.
- The additional water supplies that the City can reasonably rely upon in the future include additional SRP entitlements (as currently undeveloped, mostly agricultural lands get cut over to the City), additional reclaimed water generated within the study area, and the City's anticipated portion of lease water pursuant to the White Mountain Apache Tribe water settlement. These additional supplies will supplement the City's groundwater allowances, incidental recharge, and long-term storage credits to support future growth.

9.1.4. Water Demands vs. Supplies

- For all development and growth scenarios evaluated, the City's available SRP water entitlements are sufficient to support the City's planned land uses within On-Project Areas through build-out.
- For all development and growth scenarios evaluated, the City's remaining available water supplies (CAP allocations, long-term storage credits, groundwater allowances, reclaimed water, and the anticipated White Mountain Apache lease water) are sufficient to support the City's planned land uses within Off-Project Areas through build-out.
- The City's available water supplies are sufficient to support planned land uses under water shortage conditions represented by SRP entitlements being cut from the normal 3 AFY/acre to 2 AFY/acre and a 30 percent reduction in CAP and White Mountain Apache lease water. Given the history of SRP's robust surface water/groundwater system in supplying adequate water to its member lands and the State's achievements in firming water for the Phoenix AMA, the probability of the occurrence of these water shortage conditions is generally considered low.
- The City's available water supplies are projected to be sufficient to support planned future growth without utilizing CAGRD replenishment water.

9.1.5. Drought/Extreme Water Shortage Analysis

- Although the water shortages are considered low probability, it is prudent for the City to identify a reserve of water that should be set aside for extreme drought or prolonged water supply shortages.

- Although the occurrence of reductions in water entitlements on both the SRP and CAP systems has been non-existent or minimal in recent history, a 2005 Tree Ring Study found that there is a greater than 10 percent chance that extreme shortages in both the SRP and CAP systems simultaneously could occur in any single year.
- A conservative analysis of varying levels of reductions in SRP entitlements and CAP allocations (and WMAT lease water) occurring simultaneously indicates that, under the worse case, the City should be prepared to withdraw up to 9,800 AF of stored water from its long-term storage account in an extreme drought year at build-out demands. Thus, conservatively, the City should store, and maintain in storage, enough water to cover up to ten extreme shortage conditions over a 100 year period (10 percent probability), or a total of 98,000 AF of long-term storage credits.

9.1.6. Water Supply Alternatives

- The City's alternatives for future water production and supply include 1) continuing to build wells that will recover recharged SRP, CAP, and reclaimed water, and 2) building a new surface water treatment plant to treat the City's SRP and CAP water entitlements for direct distribution.
- The estimated 20-year life cycle costs for the Continue to Build Wells alternatives is estimated to be 20 percent less than the Building a Surface WTP alternatives.
- The cost evaluations are sensitive to the need for future groundwater treatment for arsenic, nitrates, TDS, and other constituents that are known to be present in the City's groundwater supplies. The conclusion above assumes that future wells could be located and constructed to minimize or avoid groundwater treatment. When a reasonable upper level of additional groundwater treatment is considered, the life cycle costs for the Continue to Build Wells alternatives are 10 percent less than the Build a Surface WTP alternatives.
- Groundwater modeling of the water supply alternatives indicates that the impacts of the City's future groundwater pumping will be relatively minor, amounting to less than 17 feet of additional water level drawdown over 50 years and minimal changes in groundwater flow directions.
- A weighting and ranking of decision factors important to selecting a future water supply strategy (life cycle costs, annual operation and maintenance costs, financial [bonding] capacity, source water reliability, water quality management, system operational requirements, institutional/legal constraints, carbon footprint, and public perception) indicate that the Continue to Build Wells alternatives are preferred over the Build a Surface WTP alternatives.

9.2. Basis for Recommendations

The recommended water resource management strategies are based on the significant findings and conclusions and the following additional assumptions:

- Build-out will comprise 100 percent coverage of the land uses described in the City's General Plan and the City Center and Estrella Foothills specific land use plans. Any

additional development (redevelopment, development intensification, etc.) beyond the current General Plan is not considered.

- All reclaimed water, except the 1,120 AFY that the City currently plans to continue to discharge to the Agua Fria River outfall for downstream habitat maintenance, will be recharged at the Avondale Recharge Facility.
- The City will achieve future assured water supply designations without relying on CAGRD replenished groundwater.

9.3. Recommendations

The work conducted in the Water Resource Master Plan update has identified strategies that will allow the City to provide adequate water supplies for future growth and to maintain its assured water supply status. The strategies include a recommended water supply strategy, ongoing water resource planning activities that should be continued, and additional activities that should be pursued to potentially strengthen the water supply portfolio and prepare for future updates of the Water Resource Master Plan.

9.3.1. Recommended Future Water Supply Strategy

- The City's future water supply strategy should be to continue to build wells. This strategy will be less costly than building a new surface WTP and will be easier to fund as construction of wells can be spread out over the study period and completed as demand increases dictate.
- However, because a surface WTP may provide benefits in achieving future assured water supply designations and could alleviate the need to build additional recharge capacities, and given the inherent uncertainty for future groundwater treatment, the City should lock up a site now for a potential surface WTP. This will preserve the City's future options should a treatment plant option become necessary due to regulatory, institutional, or water quality needs.

9.3.2. Ongoing City Activities

The City initiated several water resources planning activities prior to the Water Resource Master Plan update project and made a commitment to continuing these activities. The work conducted in the master plan update supports the City's commitment to continue the following ongoing activities:

- Investigating alternatives for obtaining additional recharge capacity. The investigations should include 1) determining the feasibility of re-rating the Avondale Recharge Facility to a higher capacity, 2) identifying additional recharge sites within the City's service area, and 3) potentially acquiring ownership of capacity at CAWCD recharge facilities or other recharge facilities through direct purchase and/or through exchange mechanisms. The City will start to exceed the combined capacities of the Avondale Recharge Facility and the NAUSP by 2030 for recharging reclaimed water and SRP water, sooner if the NAUSP does not achieve its design capacity

(which is currently questionable). In addition, long-term use of recharge capacity at CAWCD facilities for recharging CAP (and WMAT lease) water is not guaranteed.

- Periodically reviewing developer compliance with the policy of extinguishing Irrigation Grandfathered Groundwater Rights or Type 1 Non-Irrigation Grandfathered Groundwater Rights and pledging them to the City's Assured Water Supply Account, in order to increase the amount of groundwater "credited" to the City's Groundwater Allowance account maintained by ADWR.
- Building and setting aside a reserve of long-term storage credits sufficient for prolonged drought or shortages in SRP and CAP allocations. A reserve of 98,000 AF of stored water could offset groundwater pumping at build-out water demands if extreme annual droughts occurred on the SRP and CAP systems simultaneously 10 times over the next 100 years. The City's current long-term storage account balance is 43,626 AF, nearly half of the recommended target.
- Working with the City of Peoria to allow them to use Avondale's unused capacity in the NAUSP to recharge a portion of their reclaimed water in exchange for effluent credits. This arrangement will support the City's objective to acquire additional long-term storage credits for use during water emergencies and/or drought periods.
- As funding permits, acquiring and recharging excess CAP supplies to add to the City's long-term storage account.
- Federal legislation needed to settle the water rights claims of the White Mountain Apache Tribe is still under discussion by Congress at this time. The City will continue participating in the process as needed to secure ratification of the settlement as well as obtain a lease to a portion of the Tribe's CAP water entitlement provided by the settlement.
- Tracking the potential new ADWR policies related to future AWS Designations and the issues of physically available water within water providers' service areas versus underground storage of water outside of or remote from service areas. The City will continue to be a significantly involved stakeholder to preserve its best chances for future Designations of AWS.
- Taking steps to fully define the physically available water storage capability within the City's service area for future reclaimed water and CAP water to prepare for future AWS Designations. If there is inadequate storage capacity within the service area, the City should petition ADWR to determine that the water that *is* physically available within its service area is groundwater and stored water legally entitled to the City, and not to any other groundwater users or water stored by other users.
- Participating in the ADD Water and Access to Excess working groups as long as needed to determine future water supply impacts and to position the City for potential City shares in future water supplies.
- Permitting all new production wells as recovery wells so that all stored water can continue to be extracted and accounted for as non-groundwater supplies.

- Working with the City's environmental task force to evaluate conservation strategies that will be effective and widely supported. Cost-benefit analyses of promising additional strategies will be used to develop new recommendations. The strategies will be tied to overall water resources management and formalized into the City's draft Water Conservation Plan which it is currently preparing.

9.3.3. Other Recommendations

- The City should submit a letter of interest to CAWCD in acquiring any unallocated Non-Indian Agricultural CAP water. This is the only potentially available additional future water supply in any significant amount. This is water that has been "released" from those who initially had received an allocation of this water for any number of reasons, and is not currently allocated to any specific CAP subcontractor. While this water may be in excess of current water demand projections for the City, it may still be useful in helping to build and maintain the City's reserve drought supply, or become a supply for water demands that may occur in excess of those contemplated herein (e.g., the City's MPA south of the Estrella Mountains).
- If the City wishes to be considered for any future CAP M&I supplies that become available for any reason, it should also submit a letter of interest to ADWR and CAWCD expressing a desire to acquire any CAP M&I subcontracts that may be offered for sale. While the chances for success are unknown, the City should at least have its interest in additional CAP water on record.
- After the City receives approval of its current Application for Modification of Designation of Assured Water Supply, and as availability of renewal water supplies is strengthened (SRP, CAP, reclaimed, WMAT lease, etc.), the City should reassess its continued membership in CAGRD.
- The City should continue to geo-locate all water meters. This will enhance the review of water demand patterns and development of water demand factors in the next update of the Water Resource Master Plan.

10. References

American Water Works Association (AWWA). 1996. Forecasting Urban Water Demand.

Avondale, City of. 2002. City of Avondale General Plan. City of Avondale, Arizona (June).

Avondale, City of. 2008. General Engineering Requirements Manual. City of Avondale Arizona.

Benemelis, Perri <pfbenemelis@azwater.gov>. 2009a. CAP Reallocation. Arizona Department of Water Resources. Email to George Fletcher <water.consultant@cox.net> (October 27, 2009).

Benemelis, Perri <pfbenemelis@azwater.gov>. 2009b. CAP Reallocation. Arizona Department of Water Resources. Email to George Fletcher <water.consultant@cox.net> (October 29, 2009).

Carollo Engineers. 2005. Wastewater Collection System Master Plan & Utility Systems Evaluation. City of Avondale, Arizona (August).

Carollo Engineers. 2009. City of Avondale Water System Model Update and Analysis. City of Avondale, Arizona (June).

CH2M Hill. 2005. Reclaimed Water System Master Plan. City of Avondale, Arizona (May).

Cullom, Chuck. 2010. Brackish Groundwater Treatment and Brine Disposal Feasibility Study Discussion with George Fletcher. CAGRD (April 1, 2010).

David Evans and Associates, Inc. 2009. Estrella Foothills Specific Plan: Public Draft. City of Avondale, Arizona (September).

Dyett & Bhatia. 2008. Avondale City Center Specific Plan. City of Avondale, Arizona (August).

Fletcher, George <water.consultant@cox.net>. 2010. The CAGRD Mystery Question. Replenishment Services, LLC. Email to Tim Francis <tfrancis@pirnie.com> pertaining to CAGRD conversation with Cliff Neal.

Hirschboeck, K., M. Meko, et al. 2005. A Tree-Ring Based Assessment of Synchronous Extreme Streamflow Episodes in the Upper Colorado & Salt-Verde-Tonto River Basins: Final Report. The Salt River Project and The University of Arizona (July).

Malcolm Pirnie, Inc. 2007. Surface Water Treatment: Opportunities and Analyses. City of Avondale, Arizona (April).

Miller, J. Scott. 2010. Fourth Phoenix Active Management Area Plan Discussion. Arizona Department of Water Resources (January 27, 2010).

RBF Consulting. 2002a. Water Resources Master Plan. City of Avondale, Arizona (March).

RBF Consulting. 2002b. Water Infrastructure Master Plan. City of Avondale, Arizona (February).

Roosevelt Irrigation District. 2010. RID Participates in Groundwater Cleanup Project to Secure Clean Water for West Valley. <http://www.rooseveltirrigation.org> (accessed February 4, 2010).

Salt River Project (SRP). 1995. SRP Assured Water Supply Study for Salt River Project Member Lands (November).

Salt River Project (SRP). 2009. SRP Water Entitlement Report. City of Avondale, Arizona (August 19, 2009).

SRP. 1996. Salt River Project Guidelines and Requirements for Water Treatment Facility Siting on the SRP Water System (December).

A. Referenced City Documents

THIS PAGE INTENTIONALLY LEFT BLANK

City of Avondale Water Portfolio

ADWR No.	City Well No.	Location	Maximum Capacity (gpm)	Storage Tank (gallons)	Annual Limit per RW permit (AF)
55-608731	1	531 E. Riley Drive	1,200	200,000	no limit
55-608733	5	200 E. Mountain View Drive (irrigation)	1,200	300,000	no limit
55-501247	6	3850 N. El Mirage Road	1,650	1,200,000	2,419.4
55-501288	7	4125 N. El Mirage Road	1,600		2,419.4
55-599019	8A	1960 N. 99th Avenue	1,000	1,000,000	2,258.21
55-608792	10	12105 W. Thomas Road	1,500		no limit
55-608791	11	12139 W. Cambridge Lane	1,500		no limit
55-608793	12	2316 N. 123rd Lane	3,000		no limit
55-583017	14	1474 N. Eliseo Felix Jr. Way	1,000		970.0
55-578749	15	12533 W. Van Buren Street	600		970.0
55-200566	16	12585 W. McDowell Road	1,680		2,709.0
55-807953	16B	Friendship Park Irrigation Well	600		968.0
55-201730	17	107th Avenue and Thomas Road (SRP paired well)	1,200	1,000,000	3,461.0
55-607157	18	12855 W. McDowell Road	1,822		no limit
55-588631	19	12550 W. McDowell Road	1,500		2,420.0
55-203924	21	SEC El Mirage and Durango Road	1,820		1,468.0
55-202404	23	Encanto Boulevard and 119th Avenue	1,200		1,936.6
55-208099	20	North of Indian School on El Mirage	1,500		888.7
55-217002	22	SWC Van Buren and Avondale Boulevard			
55-210430	24	SWC 99th and McDowell Road	650		2,300.0
55-217001	25	SWC Van Buren and El Mirage Road			
55-217538	28	Whyman and 117th Ave (SRP well)	2,620	3,500,000	4,226.0

Surface Water Allocations	Acres	Rate (AF/acre)	Total (AF/year)
SRP Stored Water	4901*	3.0	14,691.0
CAP			5,416.0
Surface Water Total			20,107.0

Temporary and Future Sources	Acres	Rate (AF/acre)	Total (AF/year)
SRP Stored Water (Additional acres at build out)	1862	3.0	5586
CAP Incentive/Excess CAP (ordered for 2010 - variable thereafter)**			5000
White Mountain Apache CAP lease water (anticipated on or before 2020)			882
Reclaimed Water ***			4257
Temporary and Future Totals			10,725.0

Groundwater Allowance and Long Term Storage	Total (AF)
LTS Account Balance as of December 31, 2008	43,625.93
Effluent Credits transferred from Peoria 2008	138.84
Effluent Credits transferred from Peoria 2009****	1,004.33
Groundwater Allowance Balance	59,220.14
Total	103,989.24

* As of August 17, 2009 (Note: SRP orders are substantially less than our SRP allocation because current on project demand is substantially less than 3 AF / Acre / year)
** Not included in the total for Temporary and Future Sources
*** This value is what will be recharged at the beginning of the project and will increase as our population increases to a total of 15,179 at build out.
**** As of October 31, 2009

Wells in progress
Wells that are no longer being used

City of Avondale
Water Conservation Programs

The following tables provide a brief description of water conservation programs and services provided by Avondale's Water Conservation Office, 623-333-4400, fax 623-333-0440, 399 E. Lower Buckeye Road, Ste. 100, Avondale, AZ 85323.

CURRENT REBATE PROGRAMS AND SERVICES: Avondale

Incentives and Services	Description
Xeriscape Landscape Rebate for single family homes	Provides up to $400 incentive to install a low water use landscape and or conversion of at least 500 sq.ft. of turf area.
Irrigation Timer Rebate	Provides up to a $50 rebate for the installation of an automatic irrigation timer.
Plumbing Rebate Program	Up to a $75 rebate on qualifying toilets, and $5 rebates on qualifying showerheads.
Landscape Consultations	Consultations on low-water-use landscaping and efficient watering practices provided on-site.
Homeowner Association (HOA) Water Budgeting Assistance	Provides a summary of water saving options and a month-by-month outdoor water budget for HOAs and multi-family housing.
Investigations of water in the streets / water wasting	Water Conservation staff responds to reports of water wasting and provides educational assistance and information.

CURRENT CONSERVATION ORDINANCES: Avondale

Ordinance	Description
Chapter 4-76 plumbing Code	Ensures compliance with the Universal Plumbing Code and State statutes.
Chapter 24-160 to 24-163 Water use plans	Requires a detailed plan on the proposed uses of water in the industrial process which must demonstrate conservation-oriented techniques and the latest commercially available technology consistent with reasonable economic return.
Chapter 24-163 & section 503 Landscaping	Requirements for exterior landscaping for both residential and commercial users. Limits fountain size and placement.
Chapter 24-34 Waste of water prohibited	Consumers shall prevent unnecessary waste of water. The city reserves the right to turn water off where any waste occurs.

Water Rate Structure	Offers 3 tier rate structure for water users.
Chapter 24-33 Sprinkler restrictions	In case of water shortage or scarcity, the council may by resolution place any restriction which it deems necessary upon the use of irrigation or sprinkling purposes.
Chapter 24-170 Drought plan ordinance purpose and scope	The purpose of this ordinance is to protect the water supplies of the City of Avondale by establishing both voluntary and mandatory water conserving responses.

EDUCATIONAL PROGRAMS: Avondale

Program	Description
Free water conservation and landscape classes for homeowners	Classes with how-to information are provided with an emphasis on water efficient outdoor landscaping.
Free water conservation school assemblies. (Abracadabra Program)	Free water conservation assemblies and activity books for elementary school students.
Xeriscape demonstration	A garden demonstration at City Hall provides visitors with a visual representation of low water use plants, landscape techniques, and ideas.
Teacher Resources	Teachers are provided free resource materials and information. In-classroom presentations are provided upon request.
Project WET (water education) activities	Project WET workshops offered to teachers twice yearly.
Water Self-Audit Kits for Homeowners	Free how-to water audit kits distributed at classes and events.
Informational Brochures for residents and Homeowner's association	Pamphlets covering reclaimed water, conversions, leak detection, irrigation, landscape design and low water use plants are available at no charge.

OUTREACH PROGRAMS: Avondale

Program	Description
Member of the Arizona Municipal Water Users Association (AMWUA)	The AMWUA Conservation Committee develops outreach and educational programs and materials on a regional level.
Regional partner in the Water Use It Wisely mass media campaign	A regional mass media campaign providing an extensive outreach message to Valley residents.

Public Awareness	Water Conservation works closely with the City's Public information office to provide information to our local and regional media outlets.
Special Events	Water conservation information tables at community events provide information to thousands of residents.
Community Presentations	Provide presentations upon request to civic groups, youth programs and HOA boards.

Projected Population (Finance & Budget Estimate)

		Growth %
2009	70,000	
2010	71,750	2.5
2011	73,544	2.5
2012	75,382	2.5
2013	77,644	3
2014	79,973	3
2015	82,372	3
2016	84,843	3
2017	87,813	3.5
2018	90,886	3.5
2019	94,067	3.5
2020	97,360	3.5
2021	100,767	3.5
2022	104,798	4
2023	108,990	4
2024	112,805	3.5
2025	114,328	3.5
2026	117,186	2.5
2027	119,529	2
2028	120,725	1
2029	121,932	1
2030	123,151	1

Avondale Build Out - March 2007

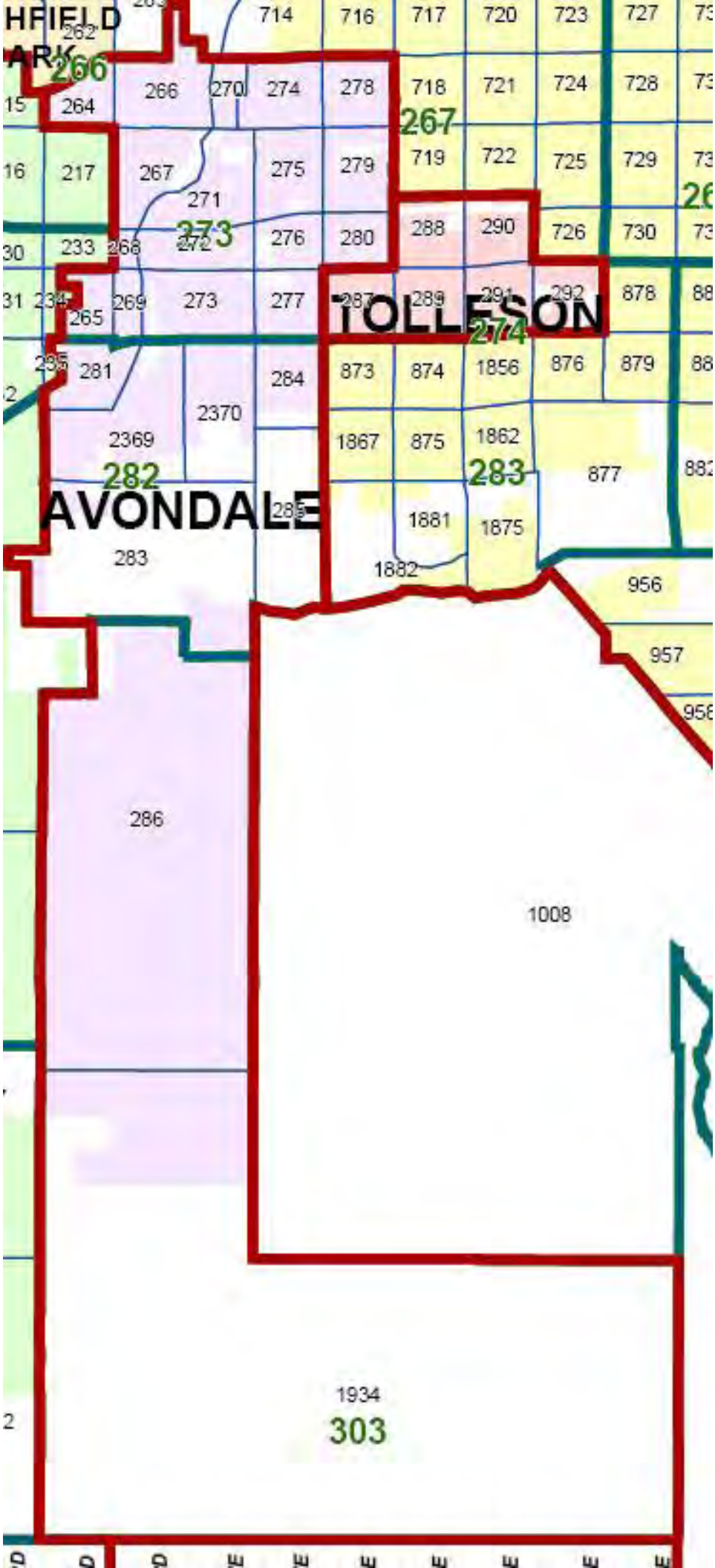
SAZ	RAZ	MPA	Total Population	Dwelling Units	Total Employment	South of PIR	Includes EF
264	273	AV	2,200	800	1,490		
265	273	AV	5,890	1,490	1,840		
266	273	AV	5,540	2,140	1,280		
267	273	AV	7,790	2,460	1,540		
268	273	AV	200	0	1,780		
269	273	AV	1,780	610	2,690		
270	273	AV	90	30	50		
271	273	AV	5,510	2,310	1,990		
272	273	AV	570	190	11,160		
273	273	AV	7,600	3,180	530		
274	273	AV	8,300	2,310	640		
275	273	AV	5,760	2,020	2,250		
276	273	AV	2,480	1,360	5,440		
277	273	AV	4,260	1,550	1,480		
278	273	AV	3,300	1,000	7,710		
279	273	AV	4,240	1,770	4,380		
280	273	AV	0	0	10,840		
281	282	AV	9,320	2,990	1,390		
283	282	AV	5,080	1,980	790		X
284	282	AV	7,330	2,590	930		X
285	282	AV	5,570	2,110	400		X
286	303	AV	810	300	1,120	X	
1934	303	AV	38,780	14,850	2,560	X	
2369	282	AV	5,750	2,390	4,390		X
2370	282	AV	7,760	3,310	1,090		X
Total Avondale MPA			145,910	53,740	69,760		

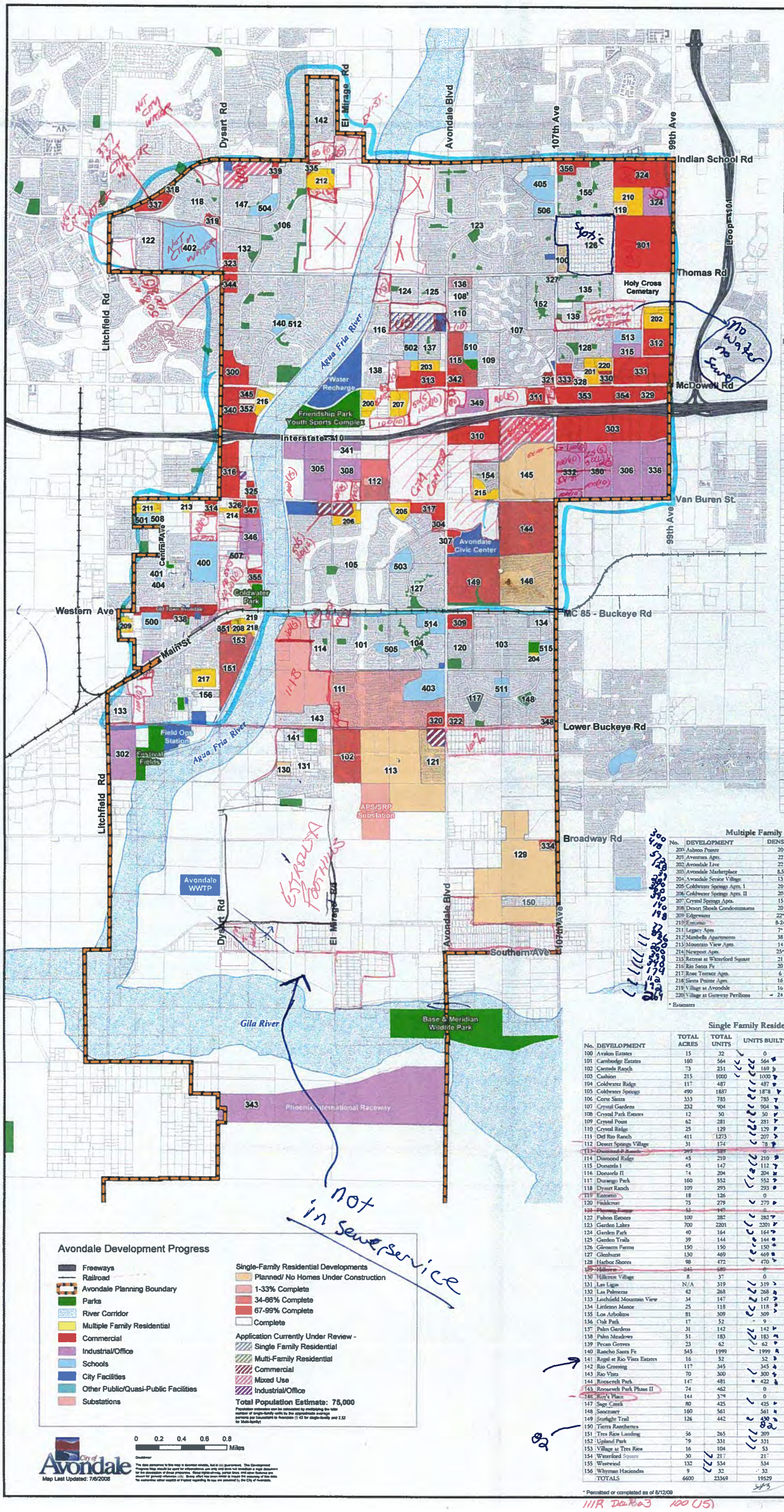
Notes :

This build out data was calculated in March 2007 as an input to the 2007 MAG Socioeconomic Projections.

Since the build out was calculated in 2007, this does not incorporate recent changes to the General Plans and known developments projects.

Data rounded to nearest 10.


HFIELD
ARK
266
262
264
266
270
274
278
714
716
717
720
723
727
718
721
724
728
267
15
16
217
267
271
275
279
719
722
725
729
273
272
276
280
288
290
726
730
30
233
268
31
234
265
269
273
277
287
289
291
292
878
TOLLESON
274
235
281
284
873
874
1856
876
879
2
2370
2369
1867
875
1862
282
283
877
AVONDALE
285
1881
1875
283
1882
956
957
286
1008
1934
303
2



High Schools/Community College

No.	NAME
400	Agua Fria High School
401	Estrella Charter High School
402	Estrella Mountain Community College
403	La Joya High School
404	Rio Salado College
405	Westview High School

Elementary/ Middle Schools

No.	NAME
500	Avondale Elementary
501	Avondale Junior High
502	Canyon Breeze Elementary
503	Collier Elementary
504	Corte Sierra Elementary
505	Estrella Vista Elementary School
506	Garden Lakes Elementary
507	Imagine Charter School
508	Lattie Coor Elementary
509	Estrella Vista Elementary School
510	Pendergast District (Future Elementary)
511	Quentin Elementary
512	Rancho Santa Fe Elementary
513	Rio Vista Elementary
514	Littleton Elementary School
515	Under Down Junior High

Commercial/ Industrial

No.	DEVELOPMENT	STATUS
300	Alameda Crossing	COMPLETE
301	Algodon Business Center	Planned
302	Anacona	Planned
303	Avondale Automall	Active
304	Avondale Coldwater 1	Planned
305	Avondale Commerce Center	Active
306	Avondale Commerce Park	Planned
307	Avondale Corporate Center	Active
308	Avondale Crossing	Planned
309	Avondale Fiesta Plaza	COMPLETE
310	Avondale Gateway	Active
311	Avondale Integrated Medical	Active
312	Avondale Live	Planned
313	Avondale Marketplace	Approved
314	Avondale Shopping Center	COMPLETE
315	CJ Studios	COMPLETE
316	Coldwater Plaza	COMPLETE
317	Coldwater Springs Promenade	Active
318	Coldwater Station	COMPLETE
319	Coronado Offices	COMPLETE
320	Del Rio Commercial	Planned
321	Desert Lakes Office	COMPLETE
322	Durango Plaza	Planned
323	Desert Commons	Active
324	Entorno	Planned
325	Estrella Vista Reception and Retail	Complete
326	Fabric Depot	Active
327	Fresh n Easy	COMPLETE
328	G & K Medical	COMPLETE
329	Gateway Crossing	Active
330	Gateway Office Park	COMPLETE
331	Gateway Pavilions	Active
332	Griffith	Active
333	Harbor Shores Executive Park	Approved
334	Hillcrest Commercial	Planned
335	Indian School Crossing	COMPLETE
336	Interstate Commerce Center	Active
337	Litchfield Park Plaza	Active
338	Old Town Avondale	COMPLETE
339	Palm Desert Plaza	COMPLETE
340	Palmilla Shopping Center	COMPLETE
341	Papago Commerce Center	Planned
342	Phoenix Children's Hospital	Approved
343	Phoenix International Raceway	Active
344	Piazza Del Campanos	Approved
345	Rancho Santa Fe Medical Center	Active
346	Rio Estrella Commerce Park	Active
347	Rio Estrella Commercial	COMPLETE
348	Sanctuary Shopping Center	Active
349	Tan Industrial	Active
350	Three Rivers Commerce Park	Approved
351	Tres Rios Commercial	Active
352	Walter A Miller Retail Center	COMPLETE
353	West 10 Corporate Center	Planned
354	West 10 Promenade	Planned
355	West Valley View	COMPLETE
356	Westwind Plaza	COMPLETE

Multiple Family Residential

No.	DEVELOPMENT	DENSITY	ACRES	STATUS
200	Ashton Pointe	20	15	Active
201	Aventura Apts.	22	19	COMPLETE
202	Avondale Live	22	26	Planned
203	Avondale Marketplace	8.5	15	Planned
204	Avondale Senior Village	13	3	COMPLETE
205	Coldwater Springs Apts. I	20	14	COMPLETE
206	Coldwater Springs Apts. II	20	18	COMPLETE
207	Crystal Springs Apts.	15	26	COMPLETE
208	Desert Shoals Condominiums	20	7	Approved
209	Edgewater	22*	9*	COMPLETE
210	Entorno	8-24	38	Planned
211	Legacy Apts	7*	11*	COMPLETE
212	Mirabella Apartments	38	22	Active
213	Mountain View Apts.	14	5	COMPLETE
214	Newport Apts.	25*	8	COMPLETE
215	Retreat at Waterford Square	21	19	COMPLETE
216	Rio Santa Fe	20	17	COMPLETE
217	Rose Terrace Apts.	6	29	COMPLETE
218	Sierra Pointe Apts.	16	7	COMPLETE
219	Village at Avondale	16	12	COMPLETE
220	Village at Gateway Pavilions	24	11	COMPLETE

* Estimates

Single Family Residential

No.	DEVELOPMENT	TOTAL ACRES	TOTAL UNITS	UNITS BUILT*	% COMPLETE	DENSITY	STATUS
100	Avalon Estates	15	32	0	0	2.2	Approved
101	Cambridge Estates	160	564	564	100	3.53	COMPLETE
102	Cantada Ranch	73	251	169	67	3.42	Active
103	Cashion	215	1000	1000	100	4.65	COMPLETE
104	Coldwater Ridge	117	487	487	100	4.16	COMPLETE
105	Coldwater Springs	490	1887	1878	99	3.60	Active
106	Corte Sierra	333	785	785	100	2.36	COMPLETE
107	Crystal Gardens	232	904	904	100	2.36	COMPLETE
108	Crystal Park Estates	12	50	50	100	4.17	COMPLETE
109	Crystal Point	62	281	281	100	4.53	COMPLETE
110	Crystal Ridge	25	129	129	100	5.16	COMPLETE
111	Del Rio Ranch	411	1273	207	16	3.43	Active
112	Desert Springs Village	31	174	78	45	5.90	Active
113	Diamond P Ranch	245	589	0	0	2.40	Approved
114	Diamond Ridge	45	210	210	100	4.67	COMPLETE
115	Donatela I	45	147	112	76	3.28	Active
116	Donatela II	74	204	204	100	3.20	COMPLETE
117	Durango Park	160	552	552	100	3.45	COMPLETE
118	Dysart Ranch	109	293	293	100	2.69	COMPLETE
119	Entorno	18	126	0	0	6	Planned
120	Fieldcrest	75	279	279	100	3.72	COMPLETE
121	[illegible]	53	147	0	0	2.94	Approved
122	Fulton Estates	100	282	282	100	2.86	COMPLETE
123	Garden Lakes	700	2201	2201	100	3.14	COMPLETE
124	Garden Park	40	164	164	100	4.10	COMPLETE
125	Garden Trails	39	144	144	100	3.69	COMPLETE
126	Glenarm Farms	150	150	150	100	1.00	COMPLETE
127	Glenhurst	130	469	469	100	3.90	COMPLETE
128	Harbor Shores	98	472	470	99	4.80	COMPLETE
129	Hillcrest	245	580	0	0	2.38	Approved
130	Hillcrest Village	8	37	0	0	4.58	Approved
131	Las Ligas	N/A	319	319	100	N/A	COMPLETE
132	Las Palmeras	42	268	268	100	6.43	COMPLETE
133	Litchfield Mountain View	34	147	147	100	4.32	COMPLETE
134	Littleton Manor	25	118	118	100	4.72	COMPLETE
135	Los Arbolitos	81	309	309	100	3.81	COMPLETE
136	Oak Park	17	52	9	17	3.63	Active
137	Palm Gardens	31	142	142	100	4.58	COMPLETE
138	Palm Meadows	51	183	183	100	3.58	COMPLETE
139	Pecan Groves	23	62	62	100	2.70	COMPLETE
140	Rancho Santa Fe	545	1999	1999	100	3.67	COMPLETE
141	Regal at Rio Vista Estates	16	52	52	100	3.75	COMPLETE
142	Rio Crossing	117	345	345	100	3.76	COMPLETE
143	Rio Vista	70	300	300	100	4.28	COMPLETE
144	Roosevelt Park	147	481	422	88	4.00	Active
145	Roosevelt Park Phase II	74	462	0	0	6.21	Approved
146	Roy's Place	144	379	0	0	2.60	Approved
147	Sage Creek	80	425	425	100	5.48	COMPLETE
148	Sanctuary	160	561	561	100	3.75	COMPLETE
149	Starlight Trail	126	442	430	97	3.52	Active
150	Tierra Ranchettes				100		COMPLETE
151	Tres Rios Landing	56	265	209	79	4.64	Active
152	Upland Park	79	331	331	100	4.19	COMPLETE
153	Village at Tres Rios	16	104	53	51	6.40	Active
154	Waterford Square	30	217	217	100	6.84	COMPLETE
155	Westwind	132	534	534	100	4.07	COMPLETE
156	Whyman Haciendas	9	32	32	100	3.70	COMPLETE
	TOTALS	6600	23369	19529			

* Permitted or completed as of 8/12/09

B. Drought Analysis

THIS PAGE INTENTIONALLY LEFT BLANK

Normal SRP and CAP Supplies

Normal SRP Supplies (2 AF/acre) Normal CAP Supplies (100%)					
	2010	2015	2020	2030	2050
Off Project Water Demands					
North of Estrella	(7,199)	(8,585)	(10,407)	(15,502)	(16,681)
Off Project Water Supplies					
North Reclaimed	2,599	3,162	3,843	5,573	5,924
CAP	5,416	5,416	5,416	5,416	5,416
WMAT		-	882	882	882
Off Project Water Balance					
	816	(7)	(266)	(3,631)	(4,459)
On Project Demand					
	(7,265)	(8,660)	(11,042)	(12,879)	(12,892)
On Project Supplies - 2+ AF/ACRE SURFACE WATER					
Reclaimed	2,602	3,114	3,925	4,717	4,722
SRP	9,980	10,870	11,760	13,526	13,526
On Project Water Balance					
SRP excess/(deficit)	2,715	2,210	718	647	634
Reclaimed Used	0	0	0	0	0
On Project Reclaimed Applied to Off Project					
	0	(7)	(266)	(3631)	(4459)
Reclaimed Stored as LTSCs					
	3,418	3,107	3,659	1,086	263
Comprehensive City Balance/(Deficit)					
	3,418	3,107	3,659	1,086	263

Reduced SRP Supplies, Normal CAP Supplies

Below Normal SRP Supplies (1.5 AF/acre) Normal CAP Supplies (100%)					
	2010	2015	2020	2030	2050
Off Project Water Demands					
North of Estrella	(7,199)	(8,585)	(10,407)	(15,502)	(16,681)
Off Project Water Supplies					
North Reclaimed	2,599	3,162	3,843	5,573	5,924
CAP	5,416	5,416	5,416	5,416	5,416
WMAT		-	882	882	882
Off Project Water Balance					
	816	(7)	(266)	(3,631)	(4,459)
On Project Demand					
	(7,265)	(8,660)	(11,042)	(12,879)	(12,892)
On Project Supplies - 1.5 AF/ACRE SURFACE WATER					
Reclaimed	2,602	3,114	3,925	4,717	4,722
SRP	7,485	8,153	8,820	10,145	10,145
On Project Water Balance					
SRP excess/(deficit)	220	(508)	(2,222)	(2,735)	(2,748)
Reclaimed Used	0	(508)	(2,222)	(2,735)	(2,748)
On Project Reclaimed Applied to Off Project					
	0	(7)	(266)	(1,983)	(1,975)
Reclaimed Stored as LTSCs					
	3,418	2,600	1,437	0	0
Comprehensive City Balance/(Deficit)					
	3,418	2,600	1,437	(1,649)	(2,485)

Dry Year SRP Supplies (1 AF/acre) Normal CAP Supplies (100%)					
	2010	2015	2020	2030	2050
Off Project Water Demands					
North of Estrella	(7,199)	(8,585)	(10,407)	(15,502)	(16,681)
Off Project Water Supplies					
North Reclaimed	2,599	3,162	3,843	5,573	5,924
CAP	5,416	5,416	5,416	5,416	5,416
WMAT		-	882	882	882
Off Project Water Balance					
	816	(7)	(266)	(3,631)	(4,459)
On Project Demand					
	(7,265)	(8,660)	(11,042)	(12,879)	(12,892)
On Project Supplies - 1 AF/ACRE SURFACE WATER					
Reclaimed	2,602	3,114	3,925	4,717	4,722
SRP	4,990	5,435	5,880	6,763	6,763
On Project Water Balance					
SRP excess/(deficit)	(2,275)	(3,225)	(5,162)	(6,116)	(6,129)
Reclaimed Used	(2,275)	(3,114)	(3,925)	(4,717)	(4,722)
On Project Reclaimed Applied to Off Project					
	0	0	0	0	0
Reclaimed Stored as LTSCs					
	1,143	0	0	0	0
Comprehensive City Balance/(Deficit)					
	1,143	(118)	(1,503)	(5,030)	(5,866)

Drought Year SRP Supplies (0.7 AF/acre) Normal CAP Supplies (100%)					
	2010	2015	2020	2030	2050
Off Project Water Demands					
North of Estrella	(7,199)	(8,585)	(10,407)	(15,502)	(16,681)
Off Project Water Supplies					
North Reclaimed	2,599	3,162	3,843	5,573	5,924
CAP	5,416	5,416	5,416	5,416	5,416
WMAT		-	882	882	882
Off Project Water Balance					
	816	(7)	(266)	(3,631)	(4,459)
On Project Demand					
	(7,265)	(8,660)	(11,042)	(12,879)	(12,892)
On Project Supplies - .7 AF/ACRE SURFACE WATER					
Reclaimed	2,602	3,114	3,925	4,717	4,722
SRP	3,493	3,805	4,116	4,734	4,734
On Project Water Balance					
SRP excess/(deficit)	(3,772)	(4,856)	(6,926)	(8,145)	(8,158)
Reclaimed Used	(3,418)	(3,114)	(3,925)	(4,717)	(4,722)
On Project Reclaimed Applied to Off Project					
	0	0	0	0	0
Reclaimed Stored as LTSCs					
	0	0	0	0	0
Comprehensive City Balance/(Deficit)					
	(354)	(1,749)	(3,267)	(7,059)	(7,895)

Normal SRP Supplies, Reduced CAP Supplies

Normal SRP Supplies (2 AF/acre) 90% CAP Supplies (CAP and WMAT)	2010	2015	2020	2030	2050
Off Project Water Demands					
North of Estrella	(7,199)	(8,585)	(10,407)	(15,502)	(16,681)
Off Project Water Supplies					
North Reclaimed	2,599	3,162	3,843	5,573	5,924
CAP	4,874	4,874	4,874	4,874	4,874
WMAT	-	-	794	794	794
Off Project Water Balance					
	274	(549)	(896)	(4,261)	(5,089)
On Project Demand					
	(7,265)	(8,660)	(11,042)	(12,879)	(12,892)
On Project Supplies					
Reclaimed	2,602	3,114	3,925	4,717	4,722
SRP	9,980	10,870	11,760	13,526	13,526
On Project Supplies - 2+ AF/ACRE SURFACE WATER					
SRP excess/(deficit)	2,715	2,210	718	647	634
Reclaimed Used	0	0	0	0	0
On Project Reclaimed Applied to Off Project					
	0	(549)	(896)	(4261)	(4722)
Reclaimed Stored as LTSCs					
	2,876	2,565	3,029	456	0
Comprehensive City Balance/(Deficit)					
	2,876	2,565	3,029	456	(367)

Normal SRP Supplies (2 AF/acre) 80% CAP Supplies (CAP and WMAT)	2010	2015	2020	2030	2050
Off Project Water Demands					
North of Estrella	(7,199)	(8,585)	(10,407)	(15,502)	(16,681)
Off Project Water Supplies					
North Reclaimed	2,599	3,162	3,843	5,573	5,924
CAP	4,333	4,333	4,333	4,333	4,333
WMAT	-	-	706	706	706
Off Project Water Balance					
	(267)	(1,090)	(1,526)	(4,891)	(5,719)
On Project Demand					
	(7,265)	(8,660)	(11,042)	(12,879)	(12,892)
On Project Supplies					
Reclaimed	2,602	3,114	3,925	4,717	4,722
SRP	9,980	10,870	11,760	13,526	13,526
On Project Supplies - 2+ AF/ACRE SURFACE WATER					
SRP excess/(deficit)	2,715	2,210	718	647	634
Reclaimed Used	0	0	0	0	0
On Project Reclaimed Applied to Off Project					
	(267)	(1090)	(1526)	(4717)	(4722)
Reclaimed Stored as LTSCs					
	2,335	2,024	2,399	0	0
Comprehensive City Balance/(Deficit)					
	2,335	2,024	2,399	(174)	(997)

Normal SRP Supplies (2 AF/acre) 70% CAP Supplies (CAP and WMAT)	2010	2015	2020	2030	2050
Off Project Water Demands					
North of Estrella	(7,199)	(8,585)	(10,407)	(15,502)	(16,681)
Off Project Water Supplies					
North Reclaimed	2,599	3,162	3,843	5,573	5,924
CAP	3,791	3,791	3,791	3,791	3,791
WMAT	-	-	617	617	617
Off Project Water Balance					
	(809)	(1,632)	(2,155)	(5,520)	(6,348)
On Project Demand					
	(7,265)	(8,660)	(11,042)	(12,879)	(12,892)
On Project Supplies					
Reclaimed	2,602	3,114	3,925	4,717	4,722
SRP	9,980	10,870	11,760	13,526	13,526
On Project Supplies - 2+ AF/ACRE SURFACE WATER					
SRP excess/(deficit)	2,715	2,210	718	647	634
Reclaimed Used	0	0	0	0	0
On Project Reclaimed Applied to Off Project					
	(809)	(1632)	(2155)	(4717)	(4722)
Reclaimed Stored as LTSCs					
	1,793	1,482	1,770	0	0
Comprehensive City Balance/(Deficit)					
	1,793	1,482	1,770	(803)	(1,626)

Below Normal SRP Supplies (1.5 AF/acre), Reduced CAP Supplies

Below Normal SRP Supplies (1.5 AF/acre) 90% CAP Supplies (CAP and WMAT)	2010	2015	2020	2030	2050
Off Project Water Demands					
North of Estrella	(7,199)	(8,585)	(10,407)	(15,502)	(16,681)
Off Project Water Supplies					
North Reclaimed	2,599	3,162	3,843	5,573	5,924
CAP	4,387	4,387	4,387	4,387	4,387
WMAT	-	-	714	714	714
Off Project Water Balance					
	(213)	(1,036)	(1,463)	(4,828)	(5,656)
On Project Demand					
	(7,265)	(8,660)	(11,042)	(12,879)	(12,892)
On Project Supplies - 1.5 AF/ACRE SURFACE WATER					
Reclaimed	2,602	3,114	3,925	4,717	4,722
SRP	7,485	8,153	8,820	10,145	10,145
On Project Water Balance					
SRP excess/(deficit)	220	(508)	(2,222)	(2,735)	(2,748)
Reclaimed Used	0	(508)	(2,222)	(2,735)	(2,748)
On Project Reclaimed Applied to Off Project					
	(213)	(1036)	(1463)	(1983)	(1975)
Reclaimed Stored as LTSCs					
	2,389	1,570	240	0	0
Comprehensive City Balance/(Deficit)					
	2,389	1,570	240	(2,845)	(3,681)

Below Normal SRP Supplies (1.5 AF/acre) 80% CAP Supplies (CAP and WMAT)	2010	2015	2020	2030	2050
Off Project Water Demands					
North of Estrella	(7,199)	(8,585)	(10,407)	(15,502)	(16,681)
Off Project Water Supplies					
North Reclaimed	2,599	3,162	3,843	5,573	5,924
CAP	3,900	3,900	3,900	3,900	3,900
WMAT	-	-	635	635	635
Off Project Water Balance					
	(700)	(1,523)	(2,029)	(5,394)	(6,222)
On Project Demand					
	(7,265)	(8,660)	(11,042)	(12,879)	(12,892)
On Project Supplies - 1.5 AF/ACRE SURFACE WATER					
Reclaimed	2,602	3,114	3,925	4,717	4,722
SRP	7,485	8,153	8,820	10,145	10,145
On Project Water Balance					
SRP excess/(deficit)	220	(508)	(2,222)	(2,735)	(2,748)
Reclaimed Used	0	(508)	(2,222)	(2,735)	(2,748)
On Project Reclaimed Applied to Off Project					
	(700)	(1523)	(1703)	(1983)	(1975)
Reclaimed Stored as LTSCs					
	1,902	1,083	0	0	0
Comprehensive City Balance/(Deficit)					
	1,902	1,083	(326)	(3,412)	(4,248)

Below Normal SRP Supplies (1.5 AF/acre) 70% CAP Supplies (CAP and WMAT)	2010	2015	2020	2030	2050
Off Project Water Demands					
North of Estrella	(7,199)	(8,585)	(10,407)	(15,502)	(16,681)
Off Project Water Supplies					
North Reclaimed	2,599	3,162	3,843	5,573	5,924
CAP	3,412	3,412	3,412	3,412	3,412
WMAT	-	556	556	556	556
Off Project Water Balance					
	(1,188)	(1,455)	(2,596)	(5,961)	(6,789)
On Project Demand					
	(7,265)	(8,660)	(11,042)	(12,879)	(12,892)
On Project Supplies - 1.5 AF/ACRE SURFACE WATER					
Reclaimed	2,602	3,114	3,925	4,717	4,722
SRP	7,485	8,153	8,820	10,145	10,145
On Project Water Balance					
SRP excess/(deficit)	220	(508)	(2,222)	(2,735)	(2,748)
Reclaimed Used	0	(508)	(2,222)	(2,735)	(2,748)
On Project Reclaimed Applied to Off Project					
	(1188)	(1455)	(1703)	(1983)	(1975)
Reclaimed Stored as LTSCs					
	1,414	1,151	0	0	0
Comprehensive City Balance/(Deficit)					
	1,414	1,151	(893)	(3,979)	(4,815)

Dry Year SRP Supplies (1.0 AF/acre), Reduced CAP Supplies

Dry Year SRP Supplies (1.0 AF/acre) 90% CAP Supplies (CAP and WMAT)	2010	2015	2020	2030	2050
Off Project Water Demands					
North of Estrella	(7,199)	(8,585)	(10,407)	(15,502)	(16,681)
Off Project Water Supplies					
North Reclaimed	2,599	3,162	3,843	5,573	5,924
CAP	4,874	4,874	4,874	4,874	4,874
WMAT	-	-	794	794	794
Off Project Water Balance					
	274	(549)	(896)	(4,261)	(5,089)
On Project Demand					
	(7,265)	(8,660)	(11,042)	(12,879)	(12,892)
On Project Supplies - 1 AF/ACRE SURFACE WATER					
Reclaimed	2,602	3,114	3,925	4,717	4,722
SRP	4,990	5,435	5,880	6,763	6,763
On Project Water Balance					
SRP excess/(deficit)	(2,275)	(3,225)	(5,162)	(6,116)	(6,129)
Reclaimed Used	(2,275)	(3,114)	(3,925)	(4,717)	(4,722)
On Project Reclaimed Applied to Off Project					
	0	0	0	0	0
Reclaimed Stored as LTSCs					
	601	0	0	0	0
Comprehensive City Balance/(Deficit)					
	601	(660)	(2,133)	(5,660)	(6,496)

Dry Year SRP Supplies (1.0 AF/acre) 80% CAP Supplies (CAP and WMAT)	2010	2015	2020	2030	2050
Off Project Water Demands					
North of Estrella	(7,199)	(8,585)	(10,407)	(15,502)	(16,681)
Off Project Water Supplies					
North Reclaimed	2,599	3,162	3,843	5,573	5,924
CAP	4,333	4,333	4,333	4,333	4,333
WMAT	-	-	706	706	706
Off Project Water Balance					
	(267)	(1,090)	(1,526)	(4,891)	(5,719)
On Project Demand					
	(7,265)	(8,660)	(11,042)	(12,879)	(12,892)
On Project Supplies - 1 AF/ACRE SURFACE WATER					
Reclaimed	2,602	3,114	3,925	4,717	4,722
SRP	4,990	5,435	5,880	6,763	6,763
On Project Water Balance					
SRP excess/(deficit)	(2,275)	(3,225)	(5,162)	(6,116)	(6,129)
Reclaimed Used	(2,275)	(3,114)	(3,925)	(4,717)	(4,722)
On Project Reclaimed Applied to Off Project					
	(267)	0	0	0	0
Reclaimed Stored as LTSCs					
	60	0	0	0	0
Comprehensive City Balance/(Deficit)					
	60	(1,201)	(2,763)	(6,290)	(7,126)

Dry Year SRP Supplies (1.0 AF/acre) 70% CAP Supplies (CAP and WMAT)	2010	2015	2020	2030	2050
Off Project Water Demands					
North of Estrella	(7,199)	(8,585)	(10,407)	(15,502)	(16,681)
Off Project Water Supplies					
North Reclaimed	2,599	3,162	3,843	5,573	5,924
CAP	3,791	3,791	3,791	3,791	3,791
WMAT	-	-	617	617	617
Off Project Water Balance					
	(809)	(1,632)	(2,155)	(5,520)	(6,348)
On Project Demand					
	(7,265)	(8,660)	(11,042)	(12,879)	(12,892)
On Project Supplies - 1 AF/ACRE SURFACE WATER					
Reclaimed	2,602	3,114	3,925	4,717	4,722
SRP	4,990	5,435	5,880	6,763	6,763
On Project Water Balance					
SRP excess/(deficit)	(2,275)	(3,225)	(5,162)	(6,116)	(6,129)
Reclaimed Used	(2,275)	(3,114)	(3,925)	(4,717)	(4,722)
On Project Reclaimed Applied to Off Project					
	(327)	0	0	0	0
Reclaimed Stored as LTSCs					
	0	0	0	0	0
Comprehensive City Balance/(Deficit)					
	(482)	(1,743)	(3,392)	(6,919)	(7,755)

Drought Year SRP Supplies (0.7 AF/acre), Reduced CAP Supplies

Drought Year SRP Supplies (0.7AF/acre) 90% CAP Supplies (CAP and WMAT)	2010	2015	2020	2030	2050
Off Project Water Demands					
North of Estrella	(7,199)	(8,585)	(10,407)	(15,502)	(16,681)
Off Project Water Supplies					
North Reclaimed	2,599	3,162	3,843	5,573	5,924
CAP	4,874	4,874	4,874	4,874	4,874
WMAT	-	-	794	794	794
Off Project Water Balance					
	274	(549)	(896)	(4,261)	(5,089)
On Project Demand					
	(7,265)	(8,660)	(11,042)	(12,879)	(12,892)
On Project Supplies - .7 AF/ACRE SURFACE WATER					
Reclaimed	2,602	3,114	3,925	4,717	4,722
SRP	3,493	3,805	4,116	4,734	4,734
On Project Water Balance					
SRP excess/(deficit)	(3,772)	(4,856)	(6,926)	(8,145)	(8,158)
Reclaimed Used	(2,876)	(3,114)	(3,925)	(4,717)	(4,722)
On Project Reclaimed Applied to Off Project					
	0	0	0	0	0
Reclaimed Stored as LTSCs					
	0	0	0	0	0
Comprehensive City Balance/(Deficit)					
	(896)	(2,290)	(3,897)	(7,689)	(8,525)

Drought Year SRP Supplies (0.7AF/acre) 80% CAP Supplies (CAP and WMAT)	2010	2015	2020	2030	2050
Off Project Water Demands					
North of Estrella	(7,199)	(8,585)	(10,407)	(15,502)	(16,681)
Off Project Water Supplies					
North Reclaimed	2,599	3,162	3,843	5,573	5,924
CAP	4,333	4,333	4,333	4,333	4,333
WMAT	-	-	706	706	706
Off Project Water Balance					
	(267)	(1,090)	(1,526)	(4,891)	(5,719)
On Project Demand					
	(7,265)	(8,660)	(11,042)	(12,879)	(12,892)
On Project Supplies - .7 AF/ACRE SURFACE WATER					
Reclaimed	2,602	3,114	3,925	4,717	4,722
SRP	3,493	3,805	4,116	4,734	4,734
On Project Water Balance					
SRP excess/(deficit)	(3,772)	(4,856)	(6,926)	(8,145)	(8,158)
Reclaimed Used	(2,602)	(3,114)	(3,925)	(4,717)	(4,722)
On Project Reclaimed Applied to Off Project					
	0	0	0	0	0
Reclaimed Stored as LTSCs					
	0	0	0	0	0
Comprehensive City Balance/(Deficit)					
	(1,437)	(2,832)	(4,527)	(8,319)	(9,155)

Drought Year SRP Supplies (0.7AF/acre) 70% CAP Supplies (CAP and WMAT)	2010	2015	2020	2030	2050
Off Project Water Demands					
North of Estrella	(7,199)	(8,585)	(10,407)	(15,502)	(16,681)
Off Project Water Supplies					
North Reclaimed	2,599	3,162	3,843	5,573	5,924
CAP	3,791	3,791	3,791	3,791	3,791
WMAT	-	-	617	617	617
Off Project Water Balance					
	(809)	(1,632)	(2,155)	(5,520)	(6,348)
On Project Demand					
	(7,265)	(8,660)	(11,042)	(12,879)	(12,892)
On Project Supplies - .7 AF/ACRE SURFACE WATER					
Reclaimed	2,602	3,114	3,925	4,717	4,722
SRP	3,493	3,805	4,116	4,734	4,734
On Project Water Balance					
SRP excess/(deficit)	(3,772)	(4,856)	(6,926)	(8,145)	(8,158)
Reclaimed Used	(2,602)	(3,114)	(3,925)	(4,717)	(4,722)
On Project Reclaimed Applied to Off Project					
	0	0	0	0	0
Reclaimed Stored as LTSCs					
	0	0	0	0	0
Comprehensive City Balance/(Deficit)					
	(1,979)	(3,373)	(5,156)	(8,948)	(9,784)

THIS PAGE INTENTIONALLY LEFT BLANK

C. Water Resource Demand Projection Tool

The water resource demand projection tool (Tool) was created to allow the City to dynamically simulate its existing and future water resource needs based on GIS land use data and land use-based demand factors. The Tool also compares the needs against the City's available water supplies. This appendix provides a general overview of the Tool, and describes the methodologies used to develop and calibrate the Tool.

C.1. General Overview

The objectives in developing the Tool were to 1) create a tool that can dynamically develop water resource demand projections (water, wastewater and reclaimed water), 2) to compare projected water demands against available supplies, and 3) to develop geospatial input for the City's water and wastewater infrastructure hydraulic models. Although geospatially allocated wastewater flow and reclaimed water projections were not included in the scope of this project, reclaimed water projections were needed to develop a portfolio of the City's available water supplies.

The Tool is a GIS-based tool that utilizes the City's GIS data in an interactive database setting to project future water resource needs quickly and easily and produces geospatial output that can be exported into infrastructure hydraulic models. The Tool allows users to change any number of planning and/or development characteristics or demand factors and to quickly recalculate water resource projections. For example, if the City accepts a proposal for a larger-than-expected development in the Estrella Foothills area, the City can quickly update the Tool to determine the development's effect on water resource and infrastructure needs. Similarly, if historical data suggest that average water use in high density residential areas has decreased, the City can adjust the demand factor and rerun the Tool to obtain revised water resource needs.

The Tool utilizes two key GIS maps, a land use map and a demand map. The land use map was created from the General Plan land use map (2002), development progress maps, and other information provided by the City. Other City GIS shapefiles such as water service providers, SRP On-Project and Off-Project Areas, etc., were overlaid with the land use map to create a demand map, which is comprised of numerous polygons resulting from the intersections. The demand map allows the user to adjust and query demands by polygon attributes such as land use type, water service provider, wastewater service provider, and development name.

Demand projections are distributed over a planning period based on estimated rates of development throughout the planning area. Water demand and wastewater flow factors

from the most recent water and wastewater master plan efforts were input into the Tool then adjusted as necessary to calibrate to existing conditions. Automated water demand and supply graph capabilities were incorporated into the Tool to allow the user to quickly compare demands and supplies. Because the Tool was developed in GIS using Visual Basic functions, it can be updated as City water supplies and developments progress over time.

C.2. Data Sources

Table C-1 provides a summary of the data sources that were used to develop the land use map, demand map, and the Tool.

Table C-1:
Projection Tool Data Sources

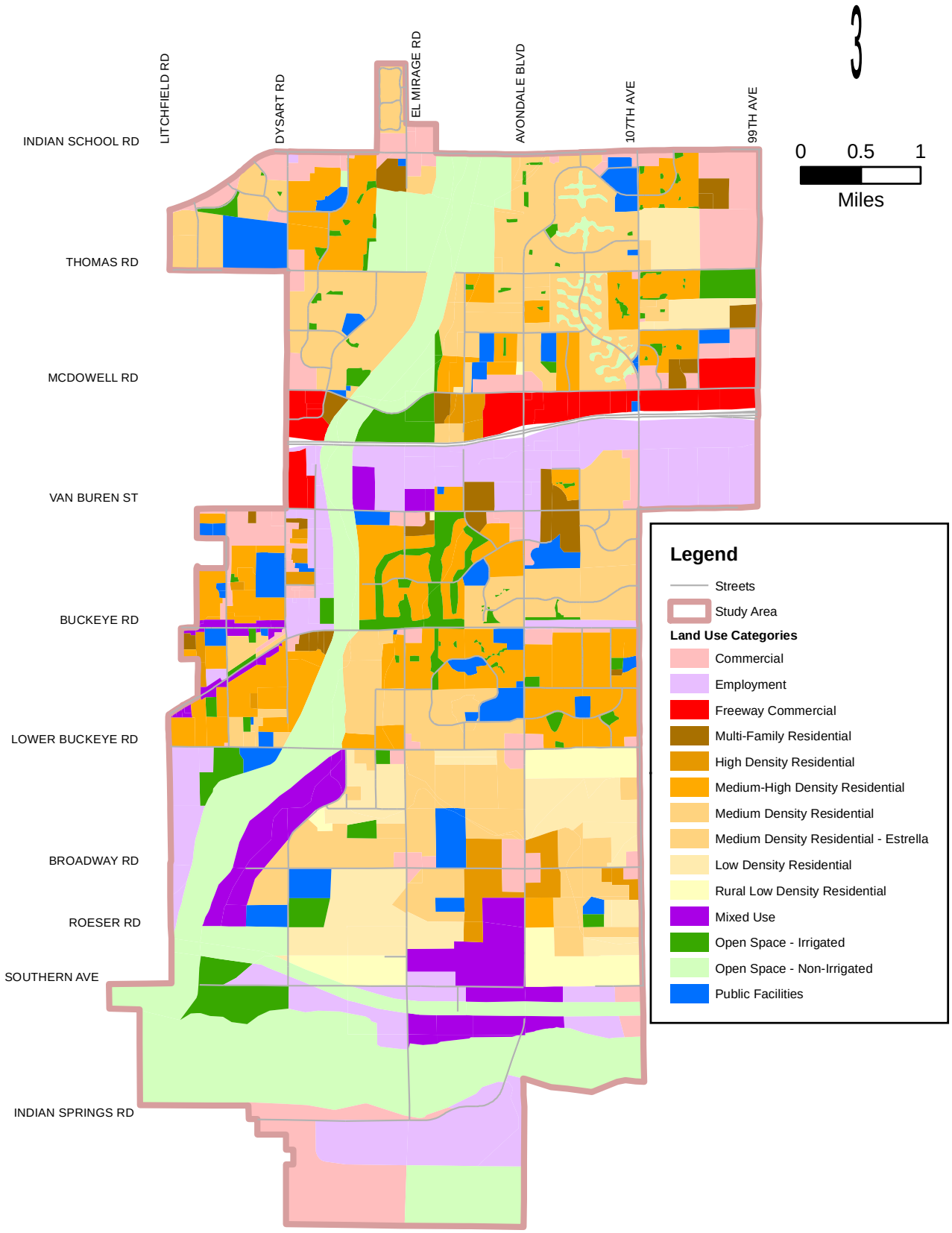
File/Report Name	Description
2009 Estrella Foothillls Specific Plan – Public Draft and shapefile (*GP_Estrella)*	Land Use Plan and rate of development for areas south of Lower Buckeye Road
2008 Avondale City Center Specific Plan	Land Use Plan for City Center (at Avondale Blvd, just south of Interstate 10)
2009 Avondale Development Progress Map and shapefiles (*commercial, developments_under_const, multifam_dev, school_public, parks, zoning_applications)*	Existing and planned developments in the City's planning area
2005 Wastewater Collection System Master Plan & Utility System Evaluation and shapefile (*Luse)*	2005 Land Use Plan (primarily used for initial land use classifications and polygon delineations); wastewater flow monitoring data used to calibrate existing wastewater flows
2007 aerial images	Used primarily to estimate percent developed for existing conditions; also used to estimate dwelling units when the data were not provided
Parcels shapefile	Used to develop lot counts for polygons in the Old Avondale area
2002 City of Avondale General Plan	Land use classifications and definitions
Water_providers shapefile	Water and wastewater service providers in the Avondale planning area (septic system areas added per City)
TAZ_projections shapefile	Used to define the City's planning area
SAZ_projections image and data	Used to calibrate build-out dwelling units south of the Estrella Mountains and north and south of Lower Buckeye Road
SRP_project_areas shapefile	Delineated SRP on and off project areas
WMACCT shapefile	Used to develop lot counts for polygons in the Old Avondale area
ss_basins shapefile	2005 wastewater flow monitoring drainage basins provided by Carollo; used to calibrate existing wastewater flows
2009 Water Model Update	Demand factors were used initially when calibrating existing system water demands

C.3. Land Use Map Development

The land use classifications in the City's 2002 General Plan land use element were used for projecting water resource demands. A land use map was developed that reflects the most up to date information on existing and planned land uses within the City planning area. The land use map developed for this master planning effort is shown on Figure C-1. The land use map was developed from existing City GIS data and information as follows:

- The land use map developed in the 2005 Wastewater Collection System Master Plan & Utility System Evaluation was used as a starting point.
- The 2005 land use map shapefile (*Luse*) was updated based on the City's 2009 Development Progress Map and associated shapefiles showing existing and planned developments (with corresponding lot counts). The dwelling unit densities listed for the existing and planned residential developments on this map were used to classify the land use type.
- Additional updates to development densities and land use classifications, particularly where development lot counts were unknown in the older parts of the City, were made using the following reference documents in order: recent geo-spatially located water meter data, the City's Parcels shapefile, and 2007 aerial photography.
- The land use map generally south of Lower Buckeye Road was replaced with the land use plan (*GP_Estrella* shapefile) in the 2009 Estrella Foothills Specific Plan. Although this specific plan has not been approved by the City Council, City planning department staff indicated that the upcoming General Plan update will be based partly on this specific plan for areas south of Lower Buckeye Road. The City suggested two small modifications to the resulting land use map: changing a Rural Low Density Residential (RLDR) polygon to a Mixed Use (MU) west of the Village Area in the Estrella Foothills area, and adding a strip of Commercial land in the Roosevelt Park development.
- The land uses for the City Center area were updated according to the 2008 City Center Specific Plan.
- All undeveloped and unplanned areas not addressed by any of the above were assigned land uses according the City's 2002 General Plan.

The resulting land use map shapefile includes attributes for each land use polygon, such as development name, lot count, dwelling unit density (calculated by dividing the total lot count by the polygon area), land use classification, and polygon acreage.



M:\0864025\GIS\MXDs\WRMP Final Report\Figure C-1 Land Use Map for City Study Area.mxd

CITY OF AVONDALE, ARIZONA
WATER RESOURCE MASTER PLAN

Land Use Map for City Study Area

MALCOLM PIRNIE

May 2010

FIGURE C-1

C.4. Demand Map Development

A demand map was developed next by overlaying (intersecting) the land use map information with other significant water supply planning characteristics of the City, including water service providers, wastewater service providers, and SRP On-Project and Off-Project Areas. The resulting demand map shown on Figure C-2 consists of 790 polygons, each with a unique identification.

C.5. Development Growth Projections

Estimates of development growth are necessary to project water resource needs throughout the planning period. The City Planning Department provided initial estimates of percentage build-outs for all undeveloped areas within the planning area for 2010 (existing), 2015, 2020, 2030, and build-out (approximately 2050). The City estimates were updated for the Estrella Foothills area based on projections provided in the 2009 DRAFT Estrella Foothills Specific Plan. Figure C-3 illustrates the development growth projections that were used.

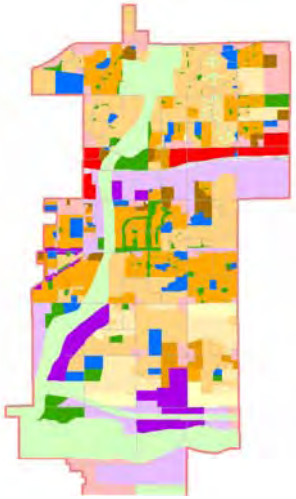
C.6. Demand Factors

Section 6 of this report presents a review of water demand and wastewater flow factors used in previous master plan efforts, as well as a cursory comparison of these demand factors with demand factors calculated from recent water demand data. Section 6 concluded the following:

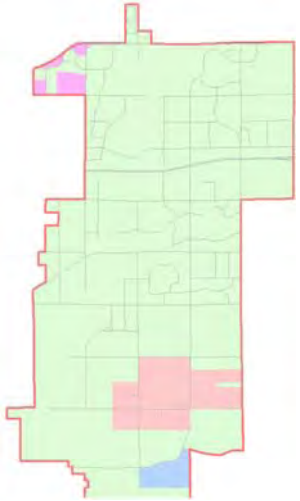
- The initial water demand factors for use in the Tool should be based on the factors developed in the 2009 Water System Model Update and Analysis.
- The initial wastewater flow factors should be based on the factors developed in the 2005 Wastewater Collection System Master Plan & Utility Systems Evaluation, including the adjustments made for specific flow monitoring drainage basins.
- A reclaimed water to wastewater factor of 0.95 should be used to project reclaimed water produced at the water reclamation facility.

C.7. Tool Calibration

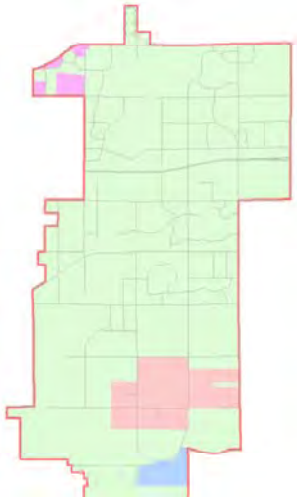
After the demand map was created and the initial demand factors were input into the Tool, the Tool was calibrated to existing and build-out conditions following the steps outlined below. The general progression for the calibration effort was to 1) match existing dwelling units, 2) adjust water demand and wastewater flow factors to match calculated demands and flows to existing (2007) demands and flows, 3) match build-out dwelling units, and 4) match the City's rate of development projections. The calibration steps are briefly described below. A summary of the calibration criteria points is provided in Table C-2.



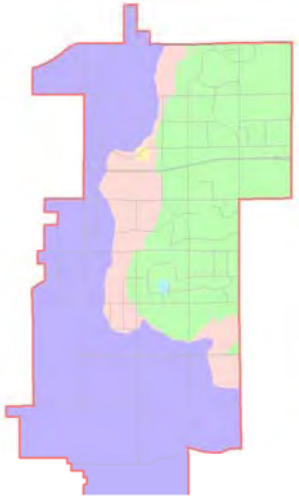
Land Use Map



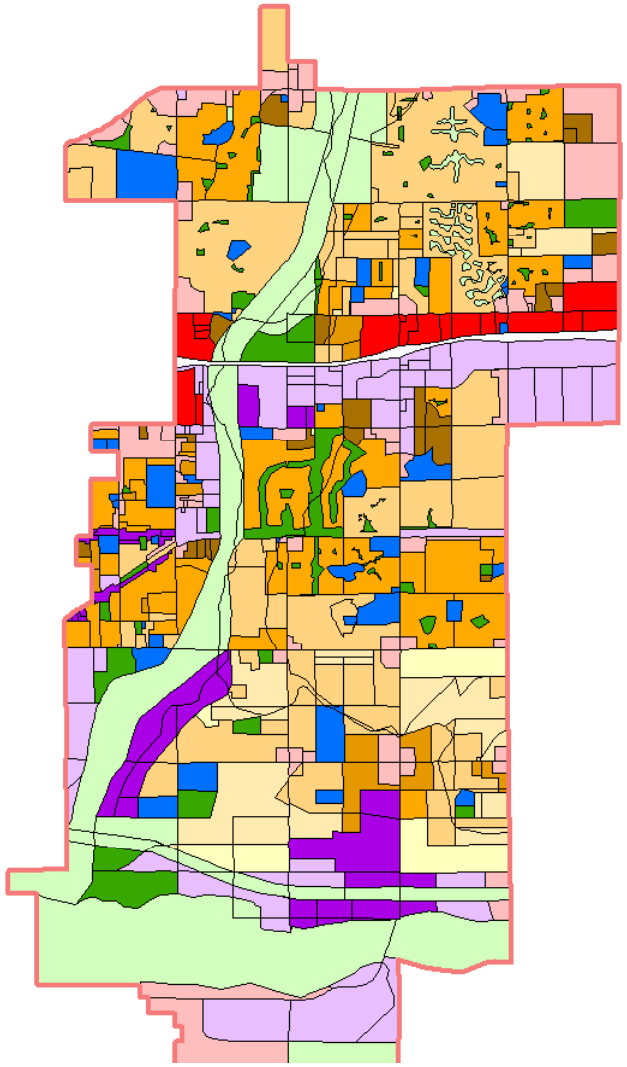
Water Service Providers



Wastewater Service Providers



SRP Project Lands

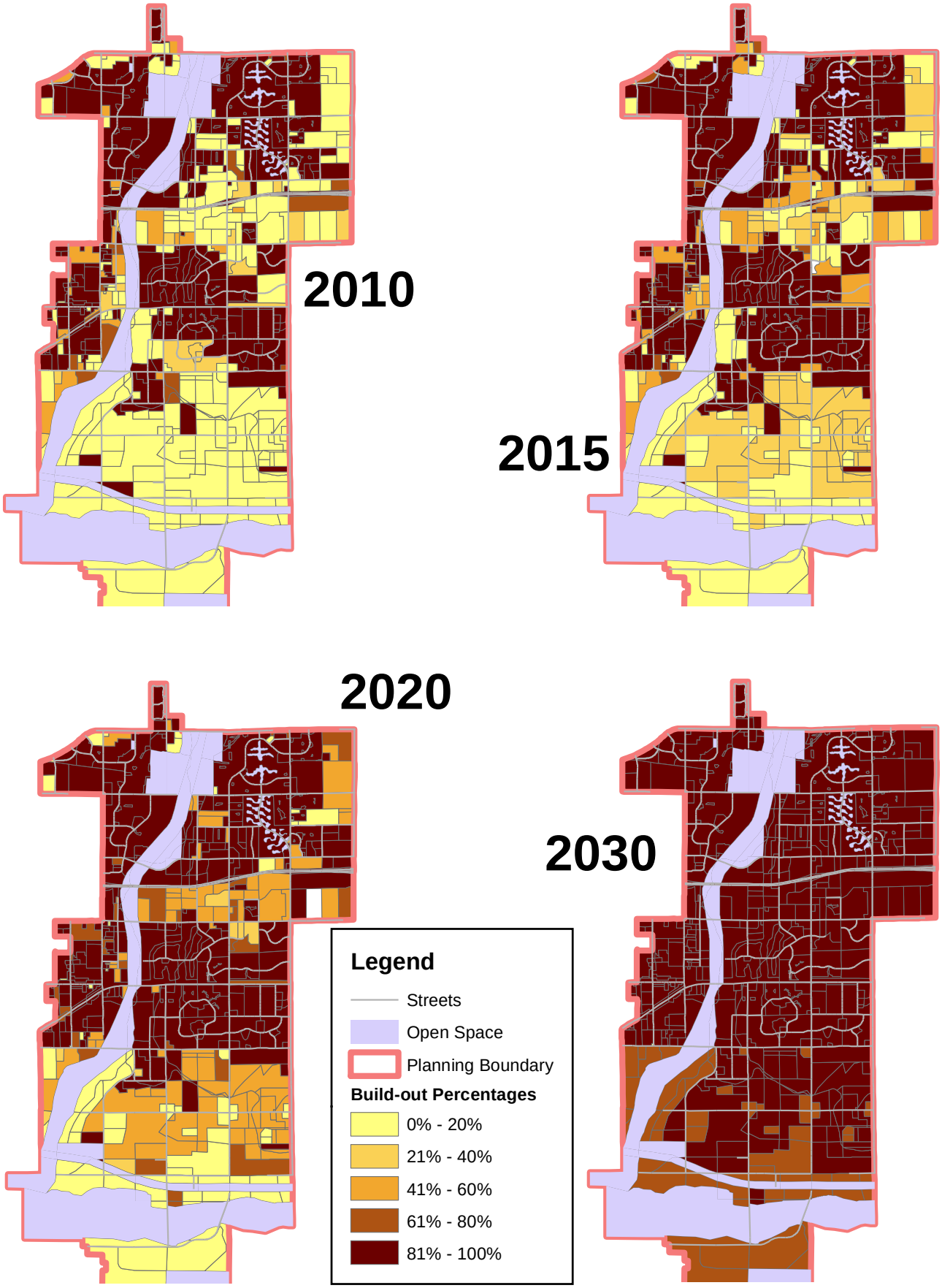


Demand Map

CITY OF AVONDALE, ARIZONA
WATER RESOURCE MASTER PLAN

Demand Map

MAY 2010
FIGURE C-2



M:\0864025\GIS\MXDs\WRMP Final Report\Figure C-3 Rate of Development.mxd

CITY OF AVONDALE, ARIZONA
WATER RESOURCE MASTER PLAN

Baseline Scenario Development Growth Projections

MALCOLM PIRNIE

May 2010

FIGURE C-3

Table C-2:
Demand Tool Calibration Points

Calibration Point	Target	Initial Values	Adjusted Values	Variance
Water	12.9 mgd	13.1 mgd	12.9 mgd	0.0%
Wastewater	4.9 mgd	6.5 mgd	4.9 mgd	0.0%
Reclaimed Water	4.7 mgd	6.2 mgd	4.7 mgd	0.0%
Existing Dwelling Units	25,964	25,969	25,969	0.0%
Build-out Dwelling Units	59,514	59,589	59,805	+0.5%
North of Lower Buckeye Road	34,960	35,006	34,945	0.0%
South of Lower Buckeye Road	9,404	10,059	9,736	+3.5%
South of Estrella Mountains	15,150	14,524	15,124	-0.2%
Rate of Development				
2010 to 2015	15%	20%	15%	0.0%
2015 to 2020	18%	23%	18%	0.0%
2020 to 2030	26%	12%	25%	-3.8%
2030 to 2050	-[1]	5%	2%	-

Note:
(1) Data not provided by the City.

- The number of existing dwelling units was verified using the City Development Progress Map (23,167 dwelling units). The Development Progress Map, however, did not include all of the residential developments in the older parts of the City. For this reason, the number of existing dwelling units was adjusted to 25,964 to account for 2,713 additional dwelling units obtained from the City's parcel shapefile, water meter locations, and 2007 aerial photographs. An estimated 84 dwelling units (based on default residential densities in the City's 2002 General Plan) were also added where aerial photographs could not be used to determine the number of homes in a particular polygon. The resulting total number of existing dwelling units was 25,964.
- The estimates of demands and flows within existing developed areas will depend largely on the estimated development status of each parcel or polygon (i.e., many parcels were not 100 percent developed). Within existing developed areas, each polygon's percent developed field (estimate of development growth) for existing conditions was estimated based on water meter data, supplemented with review of 2007 aerial images. A "1" was assigned to developments that appeared completely built-out. Similarly, a "0.5" was assigned to polygons where only 50 percent of the land was observed to be developed.
- The initial Tool run calculated an existing water demand of 13.1 mgd. Because residential developments comprised a majority of the total water demand, the initial residential demand factor (368 gpd/du) was reduced to 361 gpd/du in order to match the actual existing (2007) water production of 12.9 mgd. Table C-3 presents the initial and calibrated water demand factors. Year 2007 was selected as the calibration point because it was the year in which water demands were greatest before dipping

lower because of home foreclosures and business closings resulting from the recent national economic crisis. Year 2007 water production was also similar to water production observed in October 2009 (13 mgd).

Table C-3:
Calibrated Water Demand Factors

Land Use Category	Units	Initial Water Demand Factor[1]	Calibrated Water Demand Factor
Commercial	gpd/acre	1,850	1,850
Employment	gpd/acre	1,000	1,000
Freeway Commercial	gpd/acre	1,300	1,300
Mixed Use	gpd/acre	2,230	2,230
Open Space (Irrigated)	gpd/acre	2,300	2,300
Open Space (Non—Irrigated)	gpd/acre	0	0
Public Facilities	gpd/acre	1,000	1,000
Rural Low Density Residential	gpd/du	368	361
Low Density Residential	gpd/du	368	361
Medium Density Residential	gpd/du	368	361
Medium Density Residential - Estrella	gpd/du	368	361
Medium High Density Residential	gpd/du	368	361
High Density Residential	gpd/du	368	361
Multi-Family Residential	gpd/du	368	361

Note:
(1) 2009 Water System Model Update

- The initial wastewater flow factors resulted in a calculated existing wastewater flow of 6.5 mgd. As indicated in Section 6, the initial residential wastewater to water factor of 0.62 (62 percent of water demand results in wastewater generated) appeared a little high for southwest arid communities. Thus, the residential wastewater flow factors were reduced by 28 percent to calibrate to existing (2007) wastewater flows of 4.9 mgd. The resulting wastewater to water factor was approximately 0.45, which is more typical for southwest arid communities. Table C-4 presents the initial and calibrated wastewater flow factors. As indicated earlier, wastewater flow factors for certain flow monitoring drainage basins were adjusted to reflect the monitored flows. Table C-5 and Figure C-4, reprinted from the 2005 Wastewater Collection System Master Plan & Utility System Evaluation, were used to calibrate wastewater flow factors.
- Existing reclaimed water flow projections were confirmed in the Tool. Because reclaimed water is a function of wastewater flows, once wastewater flows were calibrated, 2007 existing reclaimed water (4.7 mgd) was calibrated as well.

Table C-4:
Calibrated Wastewater Flow Factors

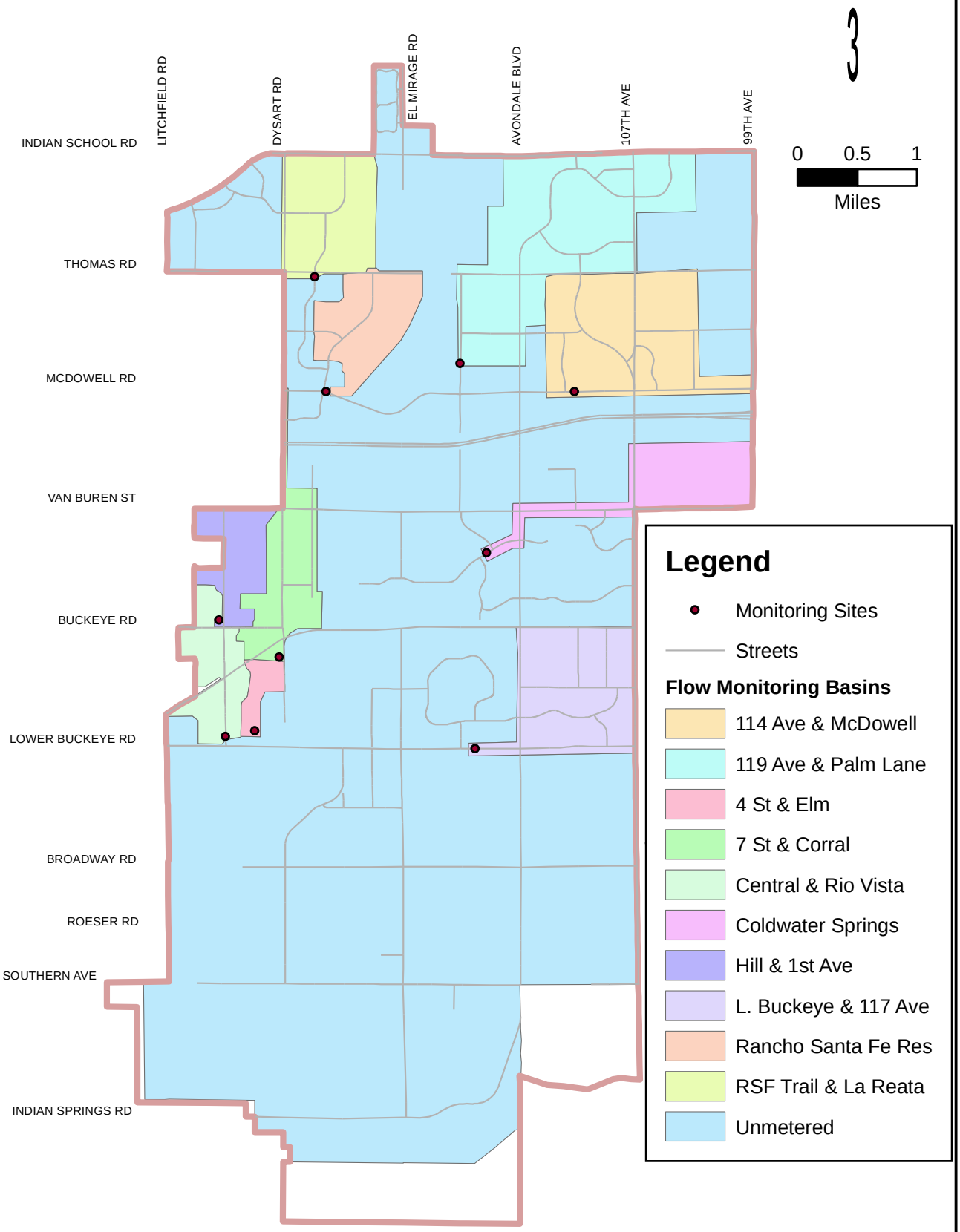
Land Use Category	Units	Initial Wastewater Flow Factor[1]	Calibrated Wastewater Flow Factor
Commercial	gpd/acre	629	629
Employment	gpd/acre	610	610
Freeway Commercial	gpd/acre	442	442
Mixed Use	gpd/acre	758	758
Open Space (Irrigated)	gpd/acre	0	0
Open Space (Non—Irrigated)	gpd/acre	0	0
Public Facilities	gpd/acre	150	150
Rural Low Density Residential	gpd/du	228	163
Low Density Residential	gpd/du	228	163
Medium Density Residential	gpd/du	228	163
Medium Density Residential - Estrella	gpd/du	228	163
Medium High Density Residential	gpd/du	228	163
High Density Residential	gpd/du	228	163
Multi-Family Residential	gpd/du	228	163

Note:
(1) 2005 Wastewater Collection System Master Plan & Utility System Evaluation

Table C-5:
Unit Load Adjustments Made Based on Temporary Meter Data

Loading (gpad)	LDR	HDR	MDR	FMDR	Commercial/ Other (C)	Large Retail (E)	Industrial	School (PF)
Unit Loads	211	1,689	834	936	757	757	698	174
114th Ave. & McDowell	211	1,689	834	936	757	757	698	174
RSF Trail & La Reata	211	1,689	834	936	757	757	698	174
119th Ave. & Palm Ln.	166	1,325	734	734	757	757	698	174
Lower Buckeye & 117th Ave.	166	1,325	734	734	757	757	698	174
McDowell @ RSF Reservoirs	166	1,325	734	734	757	757	698	174
4th St. & Elm	211	1,689	936	936	845	845	779	174
7th St. & Corral	211	1,689	936	936	845	845	779	174
Central & Rio Vista	243	1,944	1,077	1,077	1,152	1,152	892	174
Hill & 1st Ave.	243	1,944	1,077	1,077	1,200	1,200	1,000	288
Coldwater Springs	211	1,689	936	936	216	757	199	174
Unmetered	243	1,944	1,077	1,077	1,195	1,195	1,102	288

Source: Reproduced from 2005 Wastewater Collection System Master Plan & Utility System Evaluation (Table 4.3)



Source: 2005 Wastewater Collection System Master Plan & Utility Systems Evaluation

M:\0864025\GIS\MXDs\WRMP Final Report\Figure C-4 2005 Wastewater Flow Monitoring.mxd

CITY OF AVONDALE, ARIZONA
WATER RESOURCE MASTER PLAN

2005 Wastewater Flow Monitoring Locations

MALCOLM PIRNIE

May 2010

FIGURE C-4

- The number of anticipated build-out dwelling units was calculated from Maricopa Association of Governments (MAG) projections. Because the MAG projections did not incorporate the City Center or Estrella Foothills Specific Plans information, the number of build-out dwelling units was modified by replacing the respective MAG dwelling unit information with dwelling unit information from the specific plans. The median build-out dwelling units was selected from the City Center Specific Plan and the City provided the number of build-out dwelling units for the Estrella Foothills Plan. The total number of dwelling units at build-out was calculated to be 59,514. This target build-out dwelling units was allocated to areas south of the Estrella Mountains (based on MAG), Estrella Mountains to Lower Buckeye Road (based on Estrella Foothill Plan), and north of Buckeye Road (based on MAG and City Center Specific Plan).
- To match the build-out dwelling unit targets, the number of build-out dwelling units south of the Estrella Mountains was increased by increasing the residential areas by 600 acres to provide an additional 600 dwelling units. Because a land use map was loosely created in GIS from the City's General plan, adjusting the dwelling units was accomplished by reducing the *Commercial* area by 600 acres and increasing *Low Density Residential*, respectively. The number of dwelling units from the Estrella Mountains to Lower Buckeye Road was decreased by adding another land use category (Medium Density Residential Estrella) and reducing it to 2.0 du/acre, which better matches the Medium Density Residential target densities in the Estrella Foothills Plan. The number of dwelling units north of Lower Buckeye Road was decreased by reducing Medium Density Residential from 3.75 du/acre to 3.5 du/acre.
- The rate of development between 2010 and 2050 (build-out) was adjusted based on growth projections provided by the City's Finance Department (included in Appendix A of this report). In general, the initial development growth rates provided by the City Planning Department and the Estrella Foothills Specific Plan resulted in higher calculated rates of development between 2010 and 2020. To adjust this, the rate of development in Estrella Foothills was decreased between 2010 and 2020 and increased between 2020 and 2030. This adjustment projects the Estrella Foothills area to be built-out around 2030, 10 years sooner than projected in the Estrella Specific Plan.

Once the Tool had been calibrated, the resulting land uses, development densities, development growth rates, and water demand and wastewater flow factors were assigned to the "Baseline" development scenario. The calibrated Tool was used to evaluate water demand and supply balances for the Baseline scenario and alternate development scenarios as described in Section 7 of this report.

The calibrated Baseline development scenario projections correspond to the projected dwelling units shown in Table C-6.

Table C-6:
Baseline Scenario Dwelling Unit Projections

Year	Study Area Dwelling Units
2010	25,964
2015	29,854
2020	35,136
2030	43,956
2050	44,681

C.8. Water Supplies

As indicated earlier, the Tool includes graphing capabilities to quickly compare projected water demands against available water supplies. Existing and future water supplies were determined based on information provided in Sections 3 and 5 of this report. Table C-6 summarizes the water supplies that were incorporated into the Tool. It should be noted that the water supplies included in Table C-6 have specific and complex constraints (particularly SRP assessment water) regarding their use. The water supply amounts have been simplified to allow generalized demand/supply comparisons. The user can vary the amount and timing of water supplies at will based on the particular scenario or condition that is being assessed (e.g., SRP and CAP supplies can be decreased to any level to simulate potential water shortage conditions). The water supplies in Table C-7 are briefly described below:

- Groundwater Allowance is the City's groundwater allowance balance of 59,220.14 AF spread out over 100 years.
- CAP Incentive Recharge is the City's planned purchase of this water and included in the Capital Improvement Plan for fiscal years 2008 through 2012 of 5,000 AFY (total of 25,000 AF) spread out over 100 years.
- Peoria Effluent Credits are the credits that have been transferred from Peoria to Avondale in 2008 and 2009 (1,143.17 AF total) in exchange for Peoria's use of Avondale's capacity in the NAUSP facility. These credits are assumed to be spread out over 100 years.
- CAP Surface Water is the City's current CAP allocation. A high CAP allocation for normal years and a low CAP allocation for shortage conditions will be considered. Based on previous discussions, the low allocation is based on a 30 percent reduction in CAP allocations during shortage conditions.

Table C-7:
Avondale Future Water Supplies

Supply	2010		2015		2020		2030		2050	
	Low (AF)	Normal (AF)	Low (AF)	Normal (AF)	Low (AF)	Normal (AF)	Low (AF)	Normal (AF)	Low (AF)	Normal (AF)
Groundwater Allowance [1]	592		592		592		592		592	
Incidental Recharge[2]	641		764		950		1,257		1,310	
Long-Term Storage Credits [1]	436		436		436		436		436	
CAP Incentive Recharge[2]	250		250		250		250		250	
Peoria Effluent Credits [1]	11		11		11		11		11	
CAP Surface Water	3,791	5,416	3,791	5,416	3,791	5,416	3,791	5,416	3,791	5,416
SRP Assessment Water	9,980	14,970	10,870	16,305	11,760	17,640	13,526	20,289	13,526	20,289
Reclaimed Water	5,201		6,277		7,768		10,290		10,645	
WMAT Lease	0	0	0	0	617	882	617	882	617	882

Notes:
(1) City of Avondale Water Portfolio, December 2, 2009 (included in Appendix A).
(2) Water Resource Master Plan update Water Demand Projection Tool.

- SRP Assessment Water is the City's entitlements to SRP water. Based on previous discussions, the low assessment is based on 2 AFY/acre and the normal assessment is based on 3 AFY/acre. The SRP cut over acres used in Table 5-2 are based on values provided in the August 2009 SRP Water Entitlement Report. The SRP Water Entitlement Report cut over acres over time were straight lined between 2009 and 2030 (2030 is the estimated build-out for undeveloped On-Project areas based on the City's Estrella Foothills Specific Plan).
- Reclaimed Water is the reclaimed water to be produced from projected wastewater flows.
- WMAT Lease is the White Mountain Apache Tribe Indian Settlement Water that the City anticipates to start leasing on or before 2020. Similar to other CAP allocations, a high lease allotment for normal years and a low lease allotment for shortage conditions will be considered. Based on the above discussions, the low lease allotment is based on a 30 percent reduction during shortage conditions.

C.9. Tool Operation

The Tool was created in order to allow users to model water demand and supply scenarios over time. The tool was also created to ease the transition from water resource planning into water infrastructure planning. The Tool is a combination of a personal geodatabase (titled DemandAreas) and a Visual Basic application that can be installed on any computer using ArcMap 9.3. This section describes the operation of the Tool.

Tables, figures, and numbers described below were taken from the Baseline Scenario calibrated to the conditions described above.

C.9.1. User Input Tables

There are four user input tables that feed the Tool when projecting water demands and supplies: BuildoutYears, LandUseCategoryDefaults, Supply, and SRP_Factor. All tables are included in the DemandAreas personal geodatabase. ***NOTE: Only one DemandAreas geodatabase should be in an .mxd at a time. Adding multiple sets of these tables or modifying the table names will lead to calculation errors. If additional scenarios are desired, additional .mxds should be created.***

The Tool was designed with the flexibility to accommodate future water resource planning. For this reason, attributes in DemandAreas are references to Year 1 through Year 5. BuildoutYears (Table C-8) allows the user to assign a year to these reference years, which will show up on the graphs created by the Tool (Year 5 will always show up as "Build-out"). The Tool is limited to five planning years.

LandUseCategoryDefaults (Table C-9) allows the user to input demand factors for each land use classification. Residential land uses are calculated using a gpd/du factor and non-residential land uses are calculated used a gpad factor. This table also allows the user to provide a minimum, maximum, and a default dwelling unit density for the residential land uses. The default dwelling unit density is used when the density in a polygon is unknown. Additional land use categories can be added at the discretion of the user.

Table C-8:
Tool User Input Table: Buildout Years

Attributes of BuildoutYears

ID *	Buildout	BuildoutYear
1	1	2010
2	2	2015
3	3	2020
4	4	2030
5	5	2050

Record: 5 Show:

Table C-9:
Tool User Input: LandUseCategoryDefaults

Attributes of LandUseCategoryDefaults

OBJECTID *	LandUse	Description	Classification	DwellingUnitsPerAcre	MinDwellingUnitsPerAcre	MaxDwellingUnitsPerAcre	IndoorDemandFactor	Units
1	C	Commercial	Non-Residential	0	0	0	1850	gpd/acre
2	E	Employment	Non-Residential	0	0	0	1000	gpd/acre
3	HDR	High Density Residential	Residential	8	8	12	361	gpd/du
4	LDR	Low Density Residential	Residential	1	1	2	361	gpd/du
5	FRCO	Freeway Commercial	Non-Residential	0	0	0	1300	gpd/acre
6	MDR	Medium Density Residential	Residential	3.5	2	4	361	gpd/du
7	MHDR	Medium High Density Residential	Residential	4	4	8	361	gpd/du
8	MU	Mixed Use	Non-Residential	0	0	0	2230	gpd/acre
9	OS-I	Open Space - Irrigated	Non-Residential	0	0	0	2300	gpd/acre
10	PF	Public Facilities	Non-Residential	0	0	0	1100	gpd/acre
11	OS-NI	Open Space - Non-Irrigated	Non-Residential	0	0	0	0	gpd/acre
12	RLDR	Rural Low Density Residential	Residential	1	0	1	361	gpd/du
13	MFR	Multi-Family Residential	Residential	12	12	50	361	gpd/du
14	RP	Resort Potential	Non-Residential	0	0	0	1000	gpd/acre
15	MDRE	Medium Density Residential - Estrella	Residential	2	2	4	361	gpd/du

Record: 4 Show: All Selected Records (0 out of 15 Selected) Options

All of the City's available supplies are included in the supply table (Table C-10). Supply minimum and maximum fields were included to allow the user to view a range of supplies for normal and shortage years (especially in the cases of surface waters when the allocations can vary during shortages). For supplies that don't have a minimum and maximum, the same number can be entered in both fields. Additional supplies can be added by the user. The supplies will be graphed in the order in which they are in the table. The On_Project_Only column was included to specify where water supplies can be used. A "1" in the On_Project_Only field will include the supply in the On-Project Areas graph while a "0" will include it in the Off-Project Areas graph. Reclaimed water and incidental recharge are calculated automatically every time the user runs the tool (as long as the description names are not changed). SRP Water has the ability to automatically calculate, but this function has been turned off for reasons described previously and SRP supplies are currently entered manually.

Table C-10:
Tool User Input Table: Supply

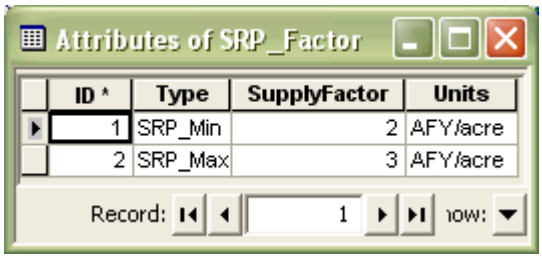
Attributes of Supply

ID *	WaterSupply	On_Project_Only	MinSupply	MaxSup	MinSupply_	MaxSupply	MinSuppl	MaxSupply	MinSupply_Y	MaxSupply_Y	MinSupply_	MaxSupply_Y
1	Groundwater	0	580	580	580	580	580	580	580	580	580	580
3	SRP Water	1	9980	14970	10870	16305	11760	17640	13526	20289	13526	20289
9	Incidental Recharge	0	640.768917	640.768	763.458067	763.458067	948.98405	948.984053	1256.484643	1256.484643	1309.27658	1309.27658
14	Storage Credits	0	630	630	630	630	630	630	630	630	630	630
15	CAP Water	0	3791	5416	3791	5416	3791	5416	3791	5416	3791	5416
16	White Mountain Apache Lease	0	0	0	617	882	617	882	617	882	617	882
17	Reclaimed Water	0	5201.10479	5201.10	6272.050263	6272.05026	7756.3370	7756.33703	10282.40962	10282.409627	10637.52578	10637.525787

Record: 1 Show: All Selected Records (0 out of 7 Selected) Options

SRP_Factor (Table C-11) provides the minimum and maximum supply factors (normal and shortage years) in which the SRP water supply is calculated. This function is currently turned off and SRP supplies are currently entered manually.

Table C-11:
Demand Tool User Input Table: SRP_Factor



ID *	Type	SupplyFactor	Units
1	SRP_Min	2	AFY/acre
2	SRP_Max	3	AFY/acre

C.9.2. Tool Calculations and Field Attributes

Within the GIS environment, the Tool is capable of calculating water demands, wastewater flows, and reclaimed water production for five planning periods. The equations used to calculate these demands as well as other field attributes used in the equations are described in Table C-12. While all the calculations can be performed manually in the GIS environment, a Visual Basic application was created to allow the user to change attributes and recalculate demands in a quick, reliable, and efficient manner, without requiring extensive knowledge of GIS software.

C.9.3. User Interface

The primary intent of the user interface (opened using the icon in the Tool) is to allow City personnel to quickly and accurately update water resource needs as undeveloped areas begin to develop. Encoded within the Tool and presented as an icon, the user interface allows users to edit field attributes for one or more polygons at a time (Figure C-5). While all attributes can technically be changed within the GIS working environment, polygon attributes such as WaterServiceProvider, WastewaterServiceProvider, and SRP will mostly likely remain constant and have been excluded from the user interface. Attributes for an individual polygon or group of polygons that can be changed by the user using the interface are described below.

Table C-12:
DemandAreas Field Attributes

Field Attribute	Description
OBJECTID	Assigned automatically: unique polygon identifier
Shape *	Assigned automatically: entry type (polygon)
WaterServiceProvider	User input: water service provider
WastewaterServiceProvider	User input: wastewater service provider
DrainageBasin	User input: wastewater drainage basin (currently null, awaiting wastewater master plan)
Landuse	User input: land use category as defined in the 2002 General Plan
Subdivision	User input: subdivision name (initially obtained from 2009 Development Progress Map)
Timeline	User input: development identifier (initially obtained from 2009 Development Progress Map)
LotCount	User input: total number of dwelling units in a development (initially obtained from 2009 Development Progress Map)
CustomType	User input: “C” for custom (DwellingUnitsPerAcre and DemandFactor do not update) or “D” for default (values taken from LandUseCategoryDefaults)
DwellingUnitsPerAcre	User input or tool input depending on CustomType: LotCount divided by ShapeArea (values for known developments were calculated initially)
DemandFactor	User input or tool input depending on CustomType: gpd/acre for non-residential and gpd/DU for residential
RWPotential	User input: created for future use (to identify polygon that can be served by reclaimed water)
WWFlowFactor	User input: ratio of wastewater flow to water demand
RWFlowFactor	User input: ratio of reclaimed water produced to wastewater flow
PercentDevelopedYearX (where X = 1-5)	User input: percent that a polygon is developed in a given year (inputted as a decimal)
DemandX (where X = 1-5)	Calculated value: residential (DwellingUnitsPerAcre * Shape_Area / 43,560 * DemandFactor) and non-residential (Shape_Area / 43,560 * DemandFactor)
WastewaterFlowX (where X = 1-5)	Calculated value: DemandX * WWFlowFactor
ReclaimedFlowX (where X = 1-5)	Calculated value: WastewaterFlowX * RWFlowFactor
SRP	User input: SRP project type (decreed, memberland, contract, off-project)
Type	User input: Residential or non-residential (used to help query the entries)
Shape_Length	Calculated value: polygon length
Shape_Area	Calculated value: polygon area

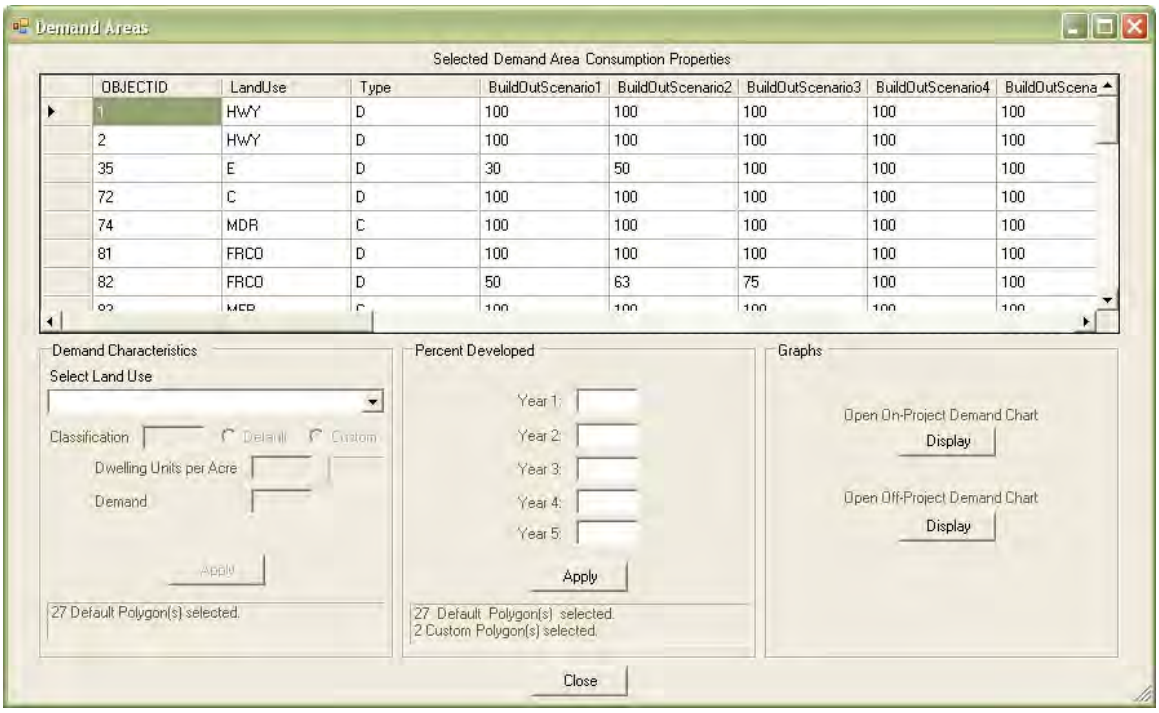


Figure C-5: Tool User Interface

Select Land Use – A drop down list that allows the user to change the land use type for a polygon. Only land use categories in LandUseCategoryDefaults can be selected.

Classification – Automatic field indicating the type of land use that was selected (residential or non-residential).

Default/Custom – Allows the user to select land use category "default" values obtained from the user input tables or input "custom" values characteristic of the polygon(s). "Custom" must be selected in order to change most of the attributes in the user interface. If "custom" is selected, the Tool will use all values appearing in the interface to calculate water resource needs

Dwelling Units per Acre – Applicable only to residential land use types, the user can enter the number of dwelling units per acre for existing or planned developments if it differs from the land use category default value.

Demand – For non-residential polygons only, the user can enter a custom water demand (gpd/acre) for the polygon if it is known.

Percent Developed: Year X – The percentage of the polygon that is developed in Year X, entered as a percent.

Open On-Project Demand Chart – Opens a chart comparing SRP On-Project supplies and demands by planning year (Figure C-6).

Open Off-Project Demand Chart – Opens a chart comparing SRP Off-Project supplies and demands by planning year (Figure C-7).

Apply – Accepts changes that were made in the interface and recalculates all demands and flows based on the updated values.

Close – Exits the user interface.

Selected Demand Area Consumption Properties – A summary of individual and total water resource needs for the selected polygon(s) which includes indoor, outdoor, and landscape demands and wastewater flows.

In addition to the User Interface icon, users can update specific polygons after they have made changes in editor mode using the icon.

Figure C-6: Example On-Project Areas Tool Graph

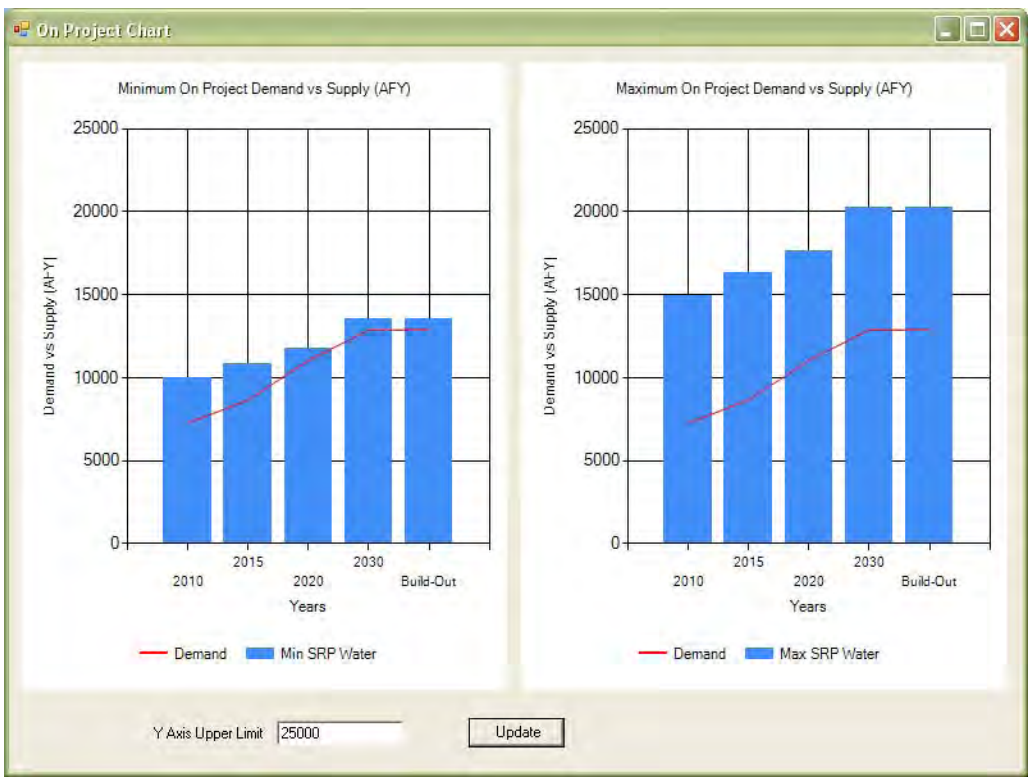


Figure C-7: Example Off-Project Areas Tool Graph

THIS PAGE INTENTIONALLY LEFT BLANK

D. Hydrogeologic Evaluation

THIS PAGE INTENTIONALLY LEFT BLANK

City of Avondale

399 East Lower Buckeye Road Suite 100. Avondale, AZ 85323

Water Resource Master Plan

Hydrogeologic Evaluation

May 2010

Report Prepared By:

Malcolm Pirnie, Inc.

4646 East Van Buren Street
Suite 400
Phoenix, AZ 85008

0864-025

MALCOLM PIRNIE

Contents

D.1. Regional Hydrogeologic Setting 2
D.2. Local Geology 6
D.2.1. Geologic Cross-Sections 6
D.2.2. Depth to Extensive Clay 12
D.3. Local Hydrogeology 12
D.3.1. Groundwater Flow 12
D.3.2. Hydraulic Properties 15
D.4. Groundwater Quality 19
D.5. Prioritizing Existing Wells for Rehabilitation/Re-drilling 35
D.6. References 38

List of Tables

Table D-1: City of Avondale Aquifer Testing Data 19

List of Figures

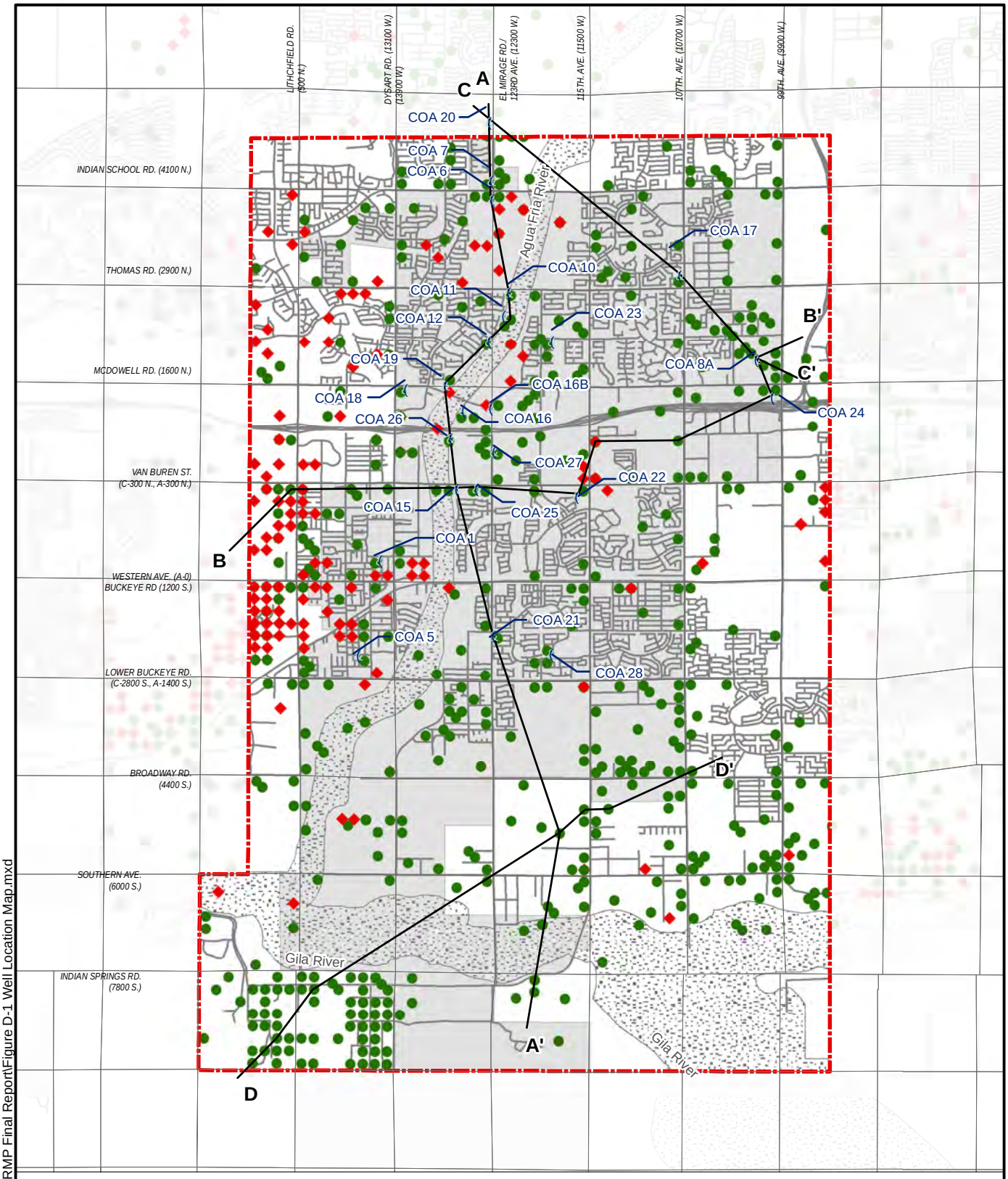
Figure D-1: Well Location Map 3
Figure D-2: Cross Section A-A' 7
Figure D-3: Cross Section B-B' 8
Figure D-4: Cross Section C-C' 9
Figure D-5: Cross Section D-D' 10
Figure D-6: Depth to Top of Extensive Clay Unit 13
Figure D-7: Groundwater Elevation Contour Map 14
Figure D-8: Hydrographs 16
Figure D-9: Aquifer Thickness Map 18
Figure D-10: Hydraulic Conductivity of the Upper Alluvial Unit 20
Figure D-11: Hydraulic Conductivity of Middle Alluvial Unit 21
Figure D-12: Hydraulic Conductivity of Lower Alluvial Unit 22
Figure D-13: Water Quality Summary Map 24
Figure D-14: Zonal Water Quality Map - TDS 26
Figure D-15: Zonal Water Quality Map - Nitrate 27
Figure D-16: Zonal Water Quality Map - Arsenic 28
Figure D-17: Zonal Water Quality Map - Fluoride 29
Figure D-18: Estimated Water Quality Contour Map - TDS 31
Figure D-19: Estimated Water Quality Contour Map - Nitrate 32
Figure D-20: Estimated Water Quality Contour Map - Arsenic 33
Figure D-21: Water Quality Favorability Map 34

The hydrogeology of the subsurface deposits underlying the City of Avondale was studied to identify favorable locations for future water supply wells. A study area was defined that encompassed the City study area (Figure D-1). The study area boundaries extend one-half mile north of Indian School Road to the north, one-half mile west of Litchfield Road to the west, one-half mile east of 99th Avenue to the east, and to Dobbins Road to the south. Available geologic, hydrogeologic, and water quality data were evaluated including, but not limited to, data sources from the ADWR, ADEQ, the United States Geological Survey (USGS), various consultant reports, and relevant internal City files. The data were evaluated to identify locations with the potential for favorable supply quantities as well as well as favorable water quality. As expressed by the City, water quality considerations were given the most weight with the goal of minimizing potential costs associated with water treatment. The basis for the identification for identification of potential new well sites is described in the following sections.

D.1. Regional Hydrogeologic Setting

The City study area lies within the Basin and Range physiographic province of the Southwest United States. The Basin and Range province is characterized as consisting of broad, gently-sloping valleys separated by steeply-sloped mountain ranges. The mountains and valleys were formed by crustal movement along high angle normal faults resulting in over 11,000 feet of structural displacement in some areas (Anderson et al., 1992). The mountains consist predominantly of consolidated granitic, volcanic, sedimentary, and metamorphic rocks that form a virtually impermeable boundary to the surrounding basins. The basins are structural depressions that have been filled with large thicknesses of alluvial sediments originating from the surrounding up-faulted mountains. The basins consist predominantly of poorly to well consolidated sand, silt, clay, and gravel with occasional volcanic and evaporite deposits (Anderson et al., 1992). The character, thickness, and areal extent of the basin deposits are highly variable and dependent on the local depositional environment.

The study area (Figure D-1) overlies the southwestern portion of the West Salt River Valley. The West Salt River Valley is bounded by the Buckeye Hills, South Mountain, and Sierra Estrella to the south, the White Tank Mountains to the west, and the Hieroglyphic Mountains to the north. Smaller mountains and hills form the eastern and northeastern boundaries of the valley. The study area primarily overlies basin-fill deposits underlying the West Salt River Valley but also includes the north slope of the Sierra Estrella.



Explanation

- City of Avondale well
- Other supply well
- Monitor or test well
- Study area
- A — A' Line of Section
- City of Avondale sevice area

Source

ADWR well registry database accessed August 2009.

City of Avondale

CITY OF AVONDALE, ARIZONA
WATER RESOURCE MASTER PLAN

Well Location Map

MALCOLM PIRNIE

May 2010

FIGURE D-1

\\phoenix\projects\0864025\GIS\MXDs\WRMP Final Report\Figure D-1 Well Location Map.mxd

The Sierra Estrella consists predominantly of crystalline metasedimentary, metavolcanic, gneissic, and granitic rocks (Brown and Pool, 1989). Although small quantities of groundwater can be found in fractures in the rock, small localized basins, or under stream channels, these rocks are not considered an aquifer on a regional scale (Brown and Pool, 1989). The study area may also be underlain by consolidated sedimentary rocks that were deposited prior to the faulting that resulted in the formation of the basin and range province. These rocks consist predominantly of reddish-colored breccia, conglomerate, sandstone, and siltstone that are likely representative of alluvial fan deposists and are collectively known as the "red unit" (Corkhill et al., 1993). Because this unit is typically well cemented and limited in areal extent, it is also not considered an aquifer on the regional scale.

The majority of the study area is underlain by basin-fill deposits. The basin-fill deposits thicken toward the center of West Salt River Valley with a maximum thickness greater than 10,000 feet (Corkhill et al., 1993). These deposits thin to a feather edge at the base of the surrounding mountain ranges. The basin-fill deposits were formed in alluvial fan, playa, and fluvial environments and make up the primary regional aquifer within the West Salt River Valley. The basin fill deposits tend to become finer-grained toward the center of valley and tend to become finer with depth (Brown and Pool, 1989). The basin fill deposits have been divided into several hydrogeologic units based on the similarity of hydraulic properties.

The basin-fill deposits of the West Salt River Valley have been subdivided by several entities including the United States Bureau of Reclamation (USBR), USGS, and ADWR. The subdivisions were similar with only minor differences in the nomenclature and definition of units. The subdivisions and nomenclature adopted by the ADWR were used for the purposes of this study.

ADWR defined three stratigraphic units referred to as the lower alluvial unit (LAU), middle alluvial unit (MAU), and upper alluvial unit (UAU). The LAU unconformably overlies the consolidated bedrock and consists predominantly of conglomerate and gravel near the basin margins grading into mudstone and gypsiferous and anhydritic mudstone at the center of the basin. The LAU is interpreted to be a result of deposition within alluvial fan environments along the margin basins that graded into fluvial, playa, and evaporitic environments toward the center of the basin (Corkhill et al., 1993). The Luke Salt body is an evaporate deposit that formed near the center of the West Salt River basin during the deposition of the LAU.

The MAU overlies the LAU and consists predominantly of silt, clay, and mudstone with interbedded layers of sand and gravel. The MAU is generally finer grained than the LAU and the UAU; however, the MAU coarsens near the margins of the valley such that it becomes difficult to distinguish it from the LAU and the UAU in these areas. Deposition

of the MAU occurred in environments similar to those of the LAU, except that playa environments were more dominant (Corkhill et al., 1993).

The UAU overlies the MAU and extends upwards to ground surface. The UAU consists predominantly of gravel and sand and silt, and tends to coarsen near former and present day river channels and near the margins of the valley. The UAU was deposited by ancestral rivers that flowed across the boundaries of basin following a long period basin enclosement (Corkhill et al., 1993).

Economical quantities of groundwater are present in each of the three basin-fill units with the primary source of water being sand, gravel, and conglomerate layers within the units. The UAU was once the largest source of groundwater in the West Salt River Valley, but is now dewatered in many areas due to extensive withdrawals. Production from the valley is now spread relatively evenly among the UAU, MAU, LAU (Rascona, 2004). The primary sources of recharge to basin fill units are from infiltration of surface water along major drainages, mountain front recharge, underflow from surrounding, up-gradient basins, and from anthropogenic sources (Anderson et al, 1992).

The major drainages within the West Salt River Valley are the Salt, Gila, and Agua Fria Rivers. Prior to development of the valley, the Salt and Gila Rivers were perennial with alternating gaining and losing reaches that either received recharge from or provided recharge to the basin-fill deposits (Corkhill et al, 1993). Since predevelopment times, the construction of dams and diversions has largely eliminated perennial flow of the Salt River upstream of the 91st avenue wastewater treatment plant, and the Gila River upstream of the confluence with the Salt River (Hammett and Herther, 1993). The remaining perennial stretches are now dominated by treated effluent discharges from wastewater treatment plants.

Prior to development, groundwater flow in the West Salt River was generally southwestward toward the Salt and Gila Rivers (Corkhill et al., 1993). Groundwater withdrawals have resulted in the development of extensive cones of depression in the center of the West Salt River valley that have diverted flow toward the center of valley away from Salt and Gila Rivers (Rascona, 2004). Water level declines of up to 300 feet feet have occurred at the center of the valley. Groundwater withdrawals have also resulted in aquifer compaction and land subsidence in some parts of the valley (Rascona, 2004).

D.2. Local Geology

Boring logs from the ADWR (ADWR, 2009a), consultant reports, and other City documents were inventoried and reviewed to characterize the local geology beneath the study area. A map of the boring locations is provided on Figure D-1. At the southern end of the study area, the boring logs revealed the presence of crystalline bedrock associated with the Sierra Estrella at shallow depths beneath the surface. Little to no basin-fill material exists at the surface in these areas, and the surficial soils consist predominantly of decomposed rock. The depth to bedrock increases rapidly north of the Gila River such that few borings north of the river were of sufficient depth to encounter the bedrock surface. These areas are underlain by large thicknesses of alluvial sediments with grain sizes ranging from silt and clay to sand and gravel.

The basin-fill sediments exhibit a general trend in which grain size becomes finer with depth. From ground surface to depths up to more than 300 feet, the basin-fill deposits consist predominantly of gravel and sand with lesser amounts of silt and clay. Beneath this surficial coarse grained layer, the basin-fill deposits become finer with varying mixtures of sand, silt, and clay predominating. Most boreholes terminate into an extensive, massive clay unit with high plasticity. The transition between individual units is typically gradational with many alternating interbeds of fine and coarse grained layers.

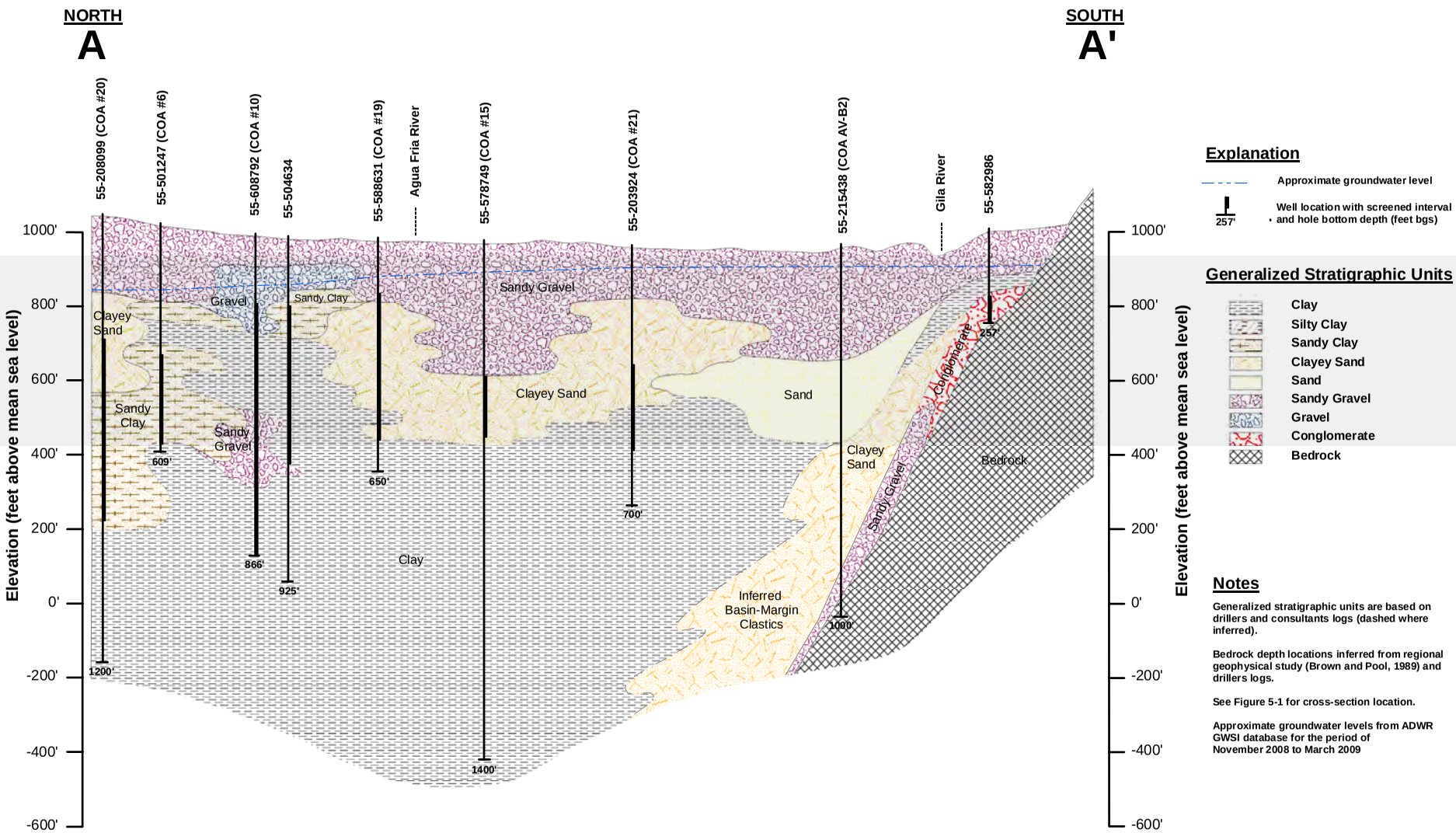
The surficial layer that is dominated by gravel and sand corresponds to the UAU. The deeper, finer-grained units correspond to the MAU. The upper portion of the MAU typically contains less clay and more coarse-grained interbeds than the lower, massive portion. Many supply wells are constructed across both the lower saturated portion of the UAU and the upper, coarser portion of the MAU. The transition from the UAU to the MAU is typically gradational such that the boundary is sometimes difficult to recognize and matter of interpretation. At some locations near the Sierra Estrella, the lower, extensive clay unit of the MAU is not present. These areas interpreted to be a coarser-grained, basin margin clastic facies of the lower MAU.

Because of its depth, the LAU is rarely encountered by borings in the study area. The exception is near the Sierra Estrella mountain front where the LAU is shallower.

D.2.1. Geologic Cross-Sections

Several geologic cross sections of the subsurface beneath the study area (Figures D-2 through D-5) were constructed from the reviewed boring logs. The cross sections utilized existing geologic information from the City's previous water master plan (RBF, 2002) and incorporated new geologic information from more recent investigations completed by the City and other entities. The locations of the cross sections are shown of Figure D-1.

Cross section A-A' extends from north to south across the middle of the study area (Figure D-2). Crystalline bedrock associated with the Sierra Estrella is present at



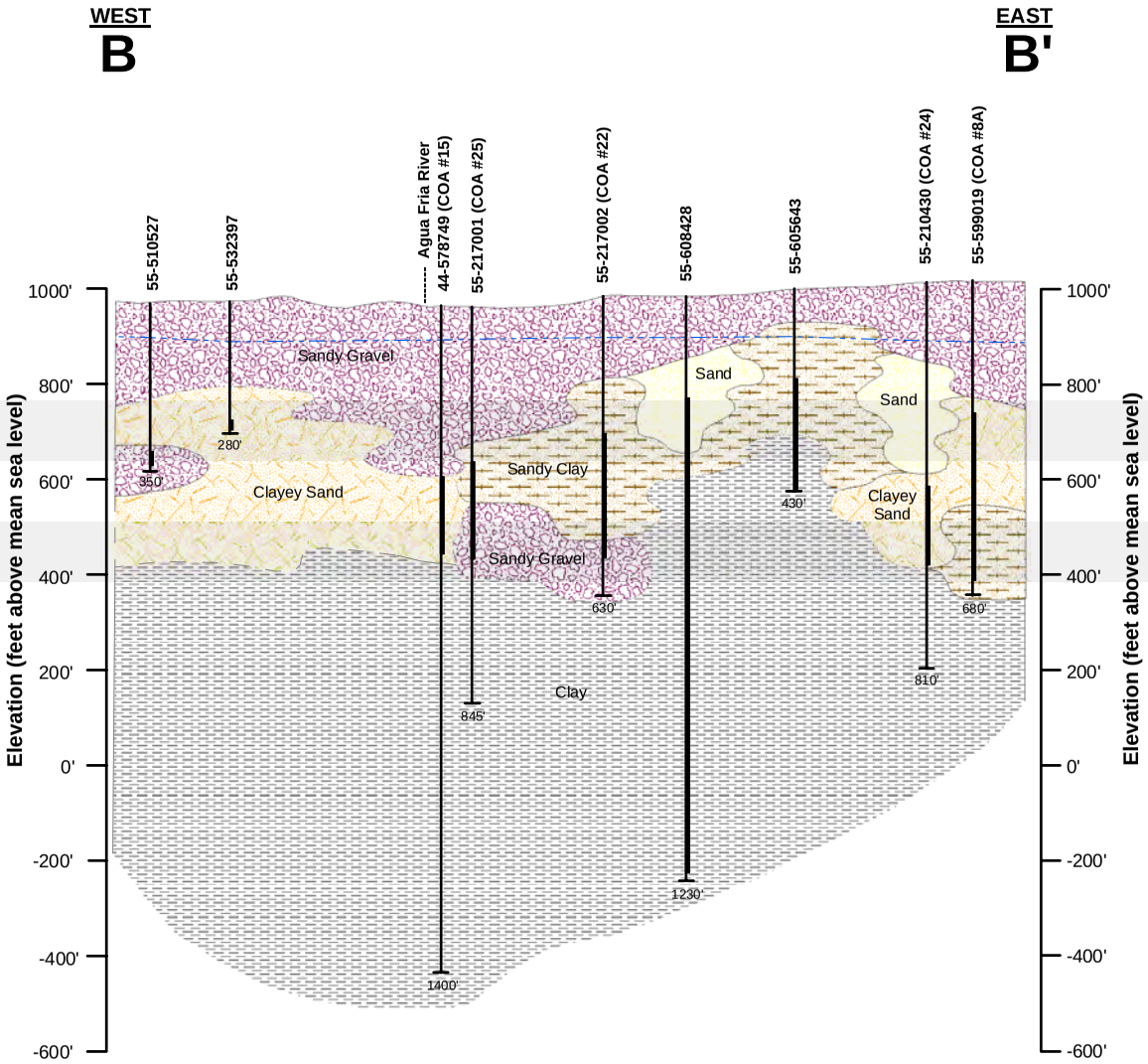
Horizontal Scale 1"= 8000'
Vertical Scale 1" = 400'
Vertical Exaggeration = 20:1
55-208099 = ADWR Well Registration Number
(COA #6) = City of Avondale Well Number

CITY OF AVONDALE, ARIZONA
WATER RESOURCE MASTER PLAN

CROSS SECTION A-A'

MALCOLM PIRNIE

May 2010
FIGURE D-2



Horizontal Scale 1"= 8000'
Vertical Scale 1" = 400'
Vertical Exaggeration = 20:1
55-208099 = ADWR Well Registration Number
(COA #6) = City of Avondale Well Number

Explanation

Approximate groundwater level

257' Well location with screened inteval and hole bottom depth (feet bgs)

Generalized Stratigraphic Units

- Clay
- Silty Clay
- Sandy Clay
- Clayey Sand
- Sand
- Sandy Gravel
- Gravel
- Conglomerate
- Bedrock

Notes

Generalized stratigraphic units are based on drillers and consultants logs (dashed where inferred).

Bedrock depth locations inferred from regional geophysical study (Brown and Pool, 1989) and drillers logs.

See Figure 5-1 for cross-section location.

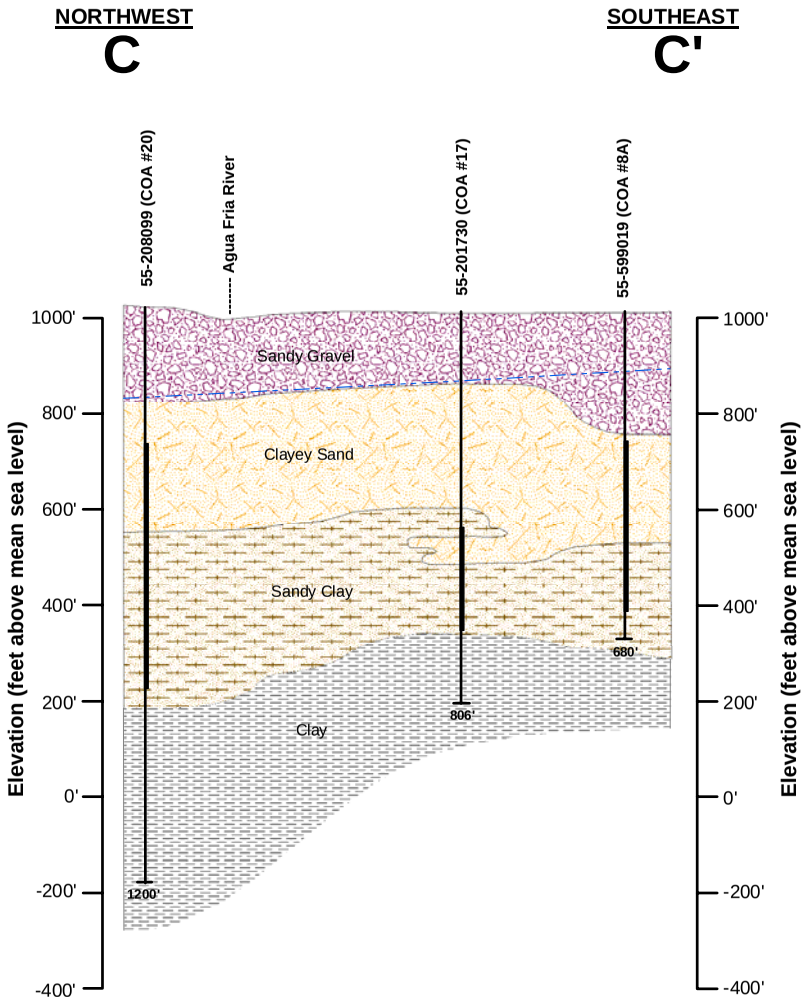
Approximate groundwater levels from ADWR GWSI database for the period of November 2008 to March 2009

CITY OF AVONDALE, ARIZONA
WATER RESOURCE MASTER PLAN

CROSS SECTION B-B'

MALCOLM PIRNIE

May 2010
FIGURE D-3



Horizontal Scale 1"= 8000'
Vertical Scale 1" = 400'
Vertical Exaggeration = 20:1
55-208099 = ADWR Well Registration Number
(COA #6) = City of Avondale Well Number

Explanation

Approximate groundwater level

257' Well location with screened interval and hole bottom depth (feet bgs)

Generalized Stratigraphic Units

- Clay
- Silty Clay
- Sandy Clay
- Clayey Sand
- Sand
- Sandy Gravel
- Gravel
- Conglomerate
- Bedrock

Notes

Generalized stratigraphic units are based on drillers and consultants logs (dashed where inferred).

Bedrock depth locations inferred from regional geophysical study (Brown and Pool, 1989) and drillers logs.

See Figure 5-1 for cross-section location.

Approximate groundwater levels from ADWR GWSI database for the period of November 2008 to March 2009

City of Avondale

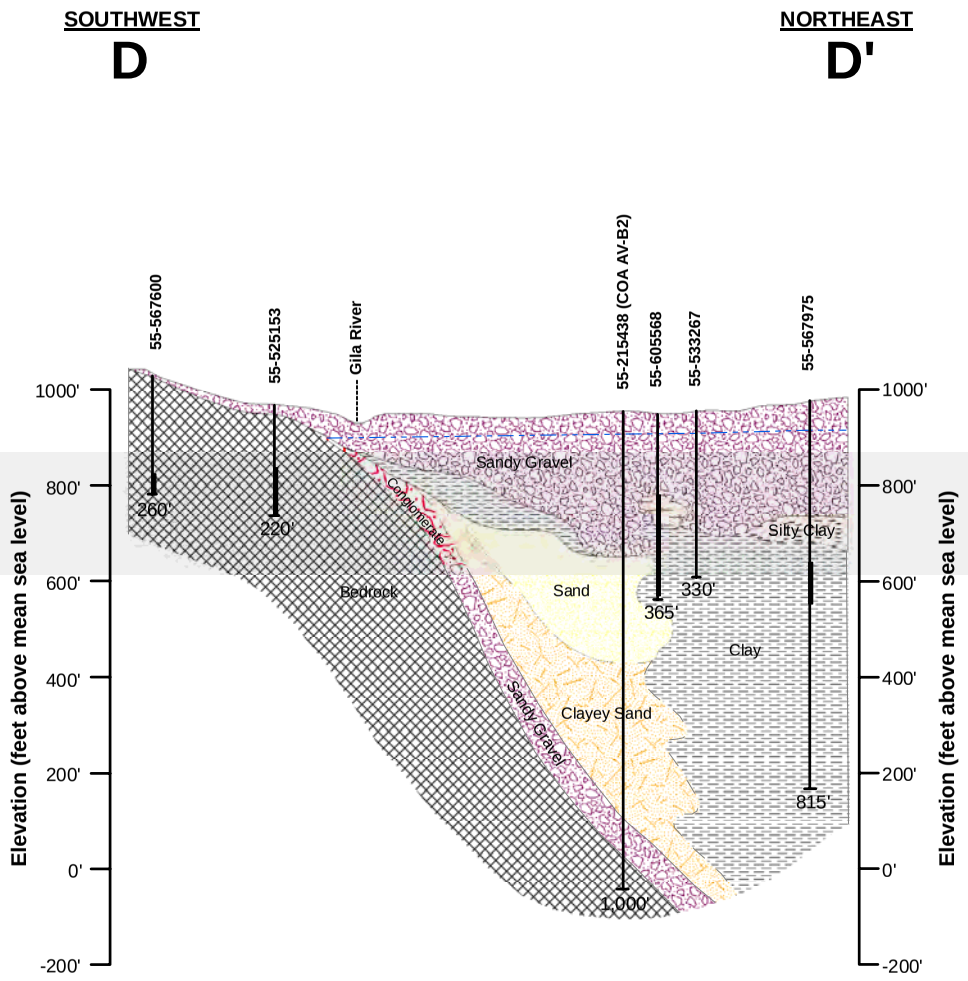
CITY OF AVONDALE, ARIZONA
WATER RESOURCE MASTER PLAN

CROSS SECTION C-C'

MALCOLM PIRNIE

May 2010

FIGURE D-4



Horizontal Scale 1"= 8000'
Vertical Scale 1" = 400'
Vertical Exaggeration = 20:1
55-208099 = ADWR Well Registration Number
(COA #6) = City of Avondale Well Number

Explanation

Approximate groundwater level

257' Well location with screened interval and hole bottom depth (feet bgs)

Generalized Stratigraphic Units

- Clay
- Silty Clay
- Sandy Clay
- Clayey Sand
- Sand
- Sandy Gravel
- Gravel
- Conglomerate
- Bedrock

Notes

Generalized stratigraphic units are based on drillers and consultants logs (dashed where inferred).

Bedrock depth locations inferred from regional geophysical study (Brown and Pool, 1989) and drillers logs.

See Figure 5-1 for cross-section location.

Approximate groundwater levels from ADWR GWSI database for the period of November 2008 to March 2009

City of Avondale

CITY OF AVONDALE, ARIZONA
WATER RESOURCE MASTER PLAN

CROSS SECTION D-D'

MALCOLM PIRNIE

May 2010
FIGURE D-5

relatively shallow depths at the southern end of the section. The elevation of the bedrock surface decreases rapidly north of the Gila River and reaches a depth of approximately 940 feet below ground surface (bgs) at COA AV-B2. Due to its great depth, the bedrock surface is not encountered by other borings further north in the section. The UAU consists predominantly of sandy gravel and gravel and extends from the surface to depths up to 340 feet bgs in the section. The maximum depth of the UAU in the section occurs at COA 15. Varying mixtures of sand and clay corresponding to the upper portion of the MAU are present beneath the UAU and above the extensive clay unit. These sediments tend to be finer and more clay-rich at the northern end of the section. The maximum depth of these sediments within the section is 830 feet bgs at COA 21. The extensive clay unit was encountered by nearly all of the borings in the section with a maximum depth of penetration of 1400 feet bgs at COA 15. However, the extensive clay unit was not encountered by COA AV-B2. The large thickness of sand and clayey sand encountered at this location is interpreted to represent a coarser-grained basin-margin, clastic facies of the lower MAU. The LAU was encountered by two borings at the southern end of the section and consisted of coarse grained sand, gravel, and conglomerate.

Cross section B-B' extends from west to east across the middle of the study area (Figure D-3). The UAU is present across the section with the greatest depth again being at COA 15. The grain size of the upper portion of the MAU varies from sandy clay to sand with minimal clay that locally grades into sandy gravel. The extensive clay unit is present across the entire section and is relatively consistent in depth except for an area just east of the middle of the section. The LAU and bedrock were not encountered by borings in the section due to their depth.

Cross section C-C' extends from northwest to southeast across the northeast section of the study area. The UAU is present across the section reaching a maximum depth of approximately 260 feet bgs at COA 8A. The upper portion of the MAU is relatively consistent across the section and grades from a clayey sand to a sandy clay with depth. The extensive clay unit was encountered by each of the borings in the section.

Cross section D-D' extends from southwest to northeast across the southern end of the study area. Bedrock is present at shallow depths under the western third of the section. Surficial soils in this area consist predominantly of decomposed rock. The elevation of the bedrock surface decreases rapidly in elevation north of the Gila River and reaches a depth of approximately 940 feet bgs at COA AV-B2 (intersection with section A-A'). The bedrock surface was not encountered by other borings further northeast in the section. The UAU is present northwest of the Gila River and extends to depths up to 310 at COA AV-B2. The top of the extensive clay is relatively shallow across most of the section, but was absent at COA AV-B2. As discussed above, the large thickness of sand and clayey sand encountered by this boring is interpreted to represent a coarser-grained,

basin-margin, clastic facies of the upper MAU. The LAU was encountered at COA-AV-B2 and is assumed to continue toward the Sierra Estrella mountain front.

D.2.2. Depth to Extensive Clay

The top of the extensive clay generally represents the maximum depth from which significant quantities of groundwater are available to supply wells. As such, the depth to the top of the extensive clay unit is an important consideration in the evaluation of potential supply quantities. The top of the extensive clay was mapped across the study area using the reviewed boring logs (Figure D-6). Boring logs from well drillers were often subjective such that identification of the top of the extensive clay was sometimes difficult. Boring logs from consultant reports provided a more reliable description of the subsurface units. The reliability of the depths to the top of the extensive clay unit for given areas are dependent on whether consultant logs were available for that area.

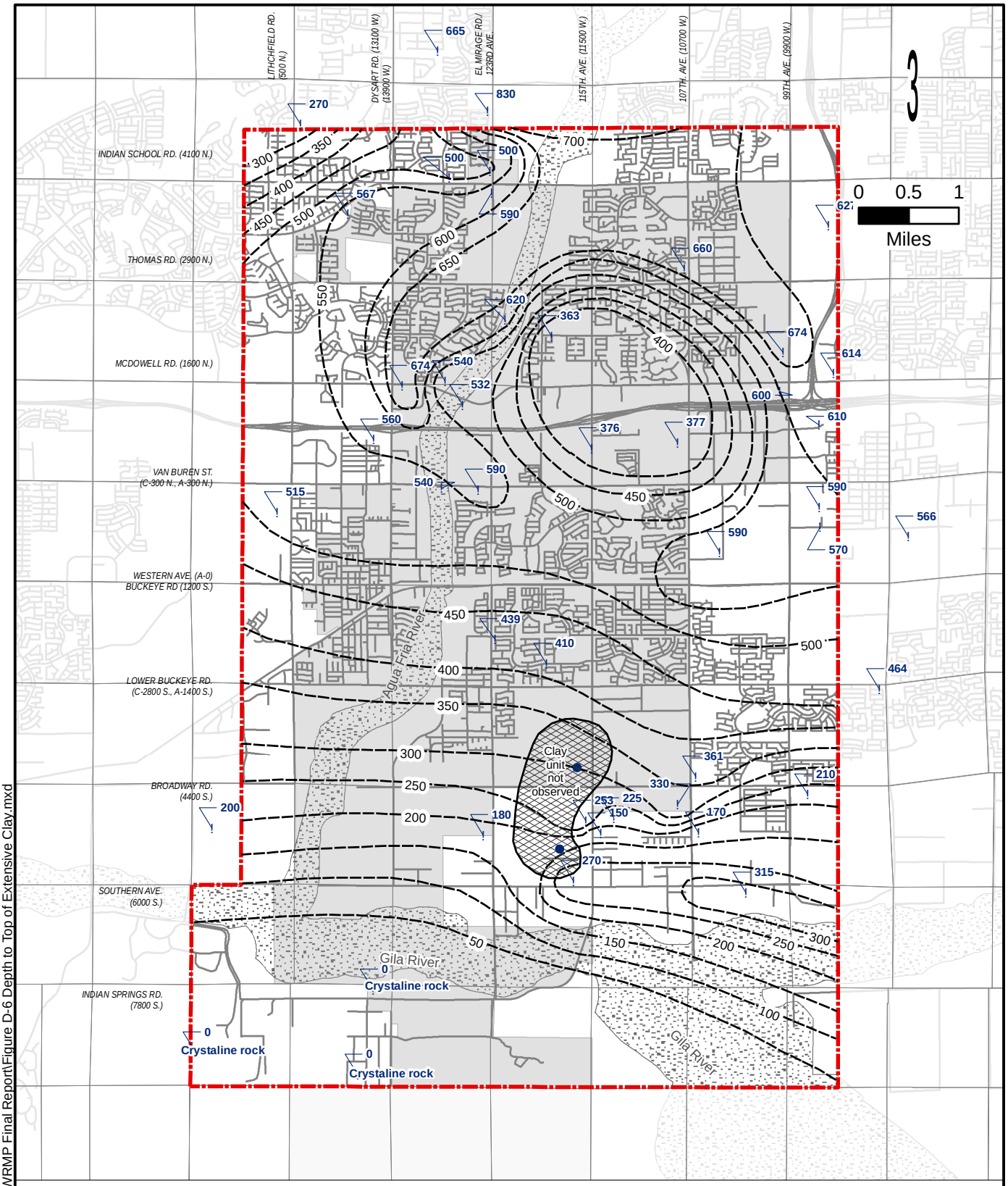
The top of the extensive clay map shows that the bottom of the shallow subsurface deposits containing coarse-grained sediments is deepest at the north end of the study area and gradually becomes shallower in the direction of the Sierra Estrella. Shallower areas also exist in the extreme northwest of the study area, and along I-10. The map also shows an area just north of the Gila River where the extensive clay unit was is not present. This represents the area where the lower MAU grades into coarser sands and clayey sands at the basin margin. It is possible that the extensive clay unit is absent in other areas near the Sierra Estrella mountain front, but these areas could not be identified due to the sparseness of reliable boring logs in these areas.

D.3. Local Hydrogeology

D.3.1. Groundwater Flow

Groundwater flows through the inter-granular pore spaces of the basin-fill sediments underlying the study area. Groundwater flow patterns within the basin-fill sediments were evaluated by preparing a groundwater elevation contour map of the study area (Figure D-7). Water level data from wells in the study area were obtained from ADWR's Groundwater Site Inventory Database (ADWR, 2009b). Winter season measurements ranging from November 2008 to March 2009 were used to construct the contour map since the least amount of pumping occurs during this period. Since most wells in the study area are screened across the UAU, the upper, coarser portion of the MAU, or both, the map is representative of the composited groundwater flow conditions within these units.

The groundwater elevation contour map shows that groundwater elevations are highest at the southern end of the study area near the Gila River. Groundwater is generally encountered at approximately 30 feet bgs in this area, and flow is westward, parallel to the Gila River. North of the Gila River, the flow direction becomes northerly and



Source

ADWR driller logs

Explanation

200 — Data point used to estimate depth to top of extensive clay unit

900 — Depth to top of extensive clay contour (feet bgs) contour interval = 50 feet

Study area

CITY OF AVONDALE, ARIZONA
WATER RESOURCE MASTER PLAN

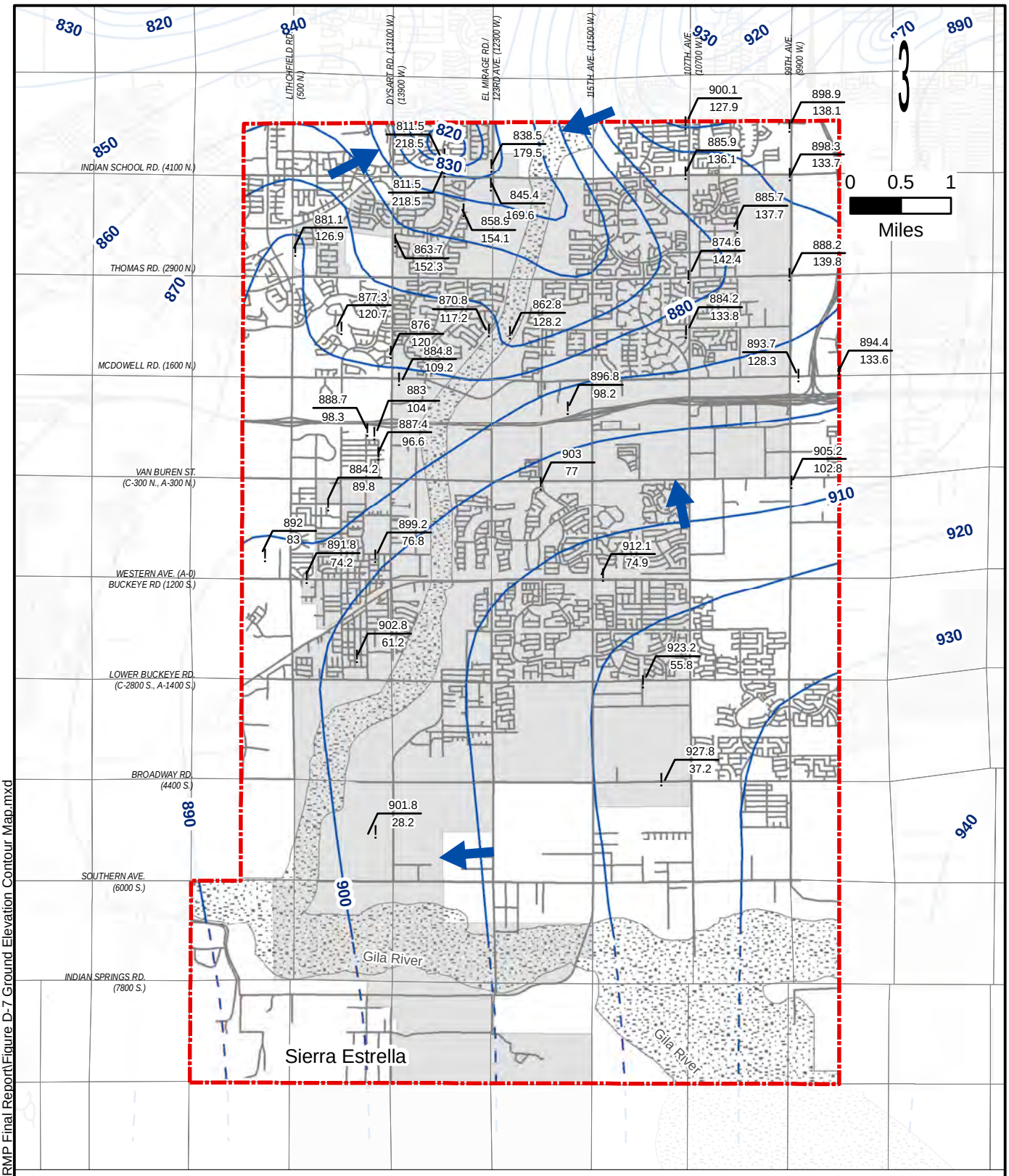
Depth to Top of Extensive Clay

MALCOLM PIRNIE

May 2010

FIGURE D-6

\\phoenix\projects\0864025\GIS\MXDs\WRMP Final Report\Figure D-6 Depth to Top of Extensive Clay.mxd



Source

ADWR water level database -- water levels measured between November 2008 and March 2009.

Explanation

848.1 / 50.5	Water level elevation (feet above mean sea level) / Depth to water (feet below ground surface)
900	Water level contour (feet above mean sea level) Dashed where inferred, contour interval = 10 feet
	Study area
	Approximate groundwater flow direction

CITY OF AVONDALE, ARIZONA
WATER RESOURCE MASTER PLAN

Groundwater Elevation Contour Map

MALCOLM PIRNIE

May 2010

FIGURE D-7

\\phoenix\projects\0864025\GIS\MXDs\WRMP Final Report\Figure D-7 Ground Elevation Contour Map.mxd

northwesterly towards the pumping centers to the north of the study area. The minimum measured water level elevation in the study area was 811.5 feet amsl (218.5 feet bgs) northwest of the intersection of Indian School and El Mirage Road. The water level data suggest a general flow pattern in which recharge enters the aquifer from the Gila River and perhaps from the Sierra Estrella mountain front and travels to the north toward major pumping centers where much of it is extracted.

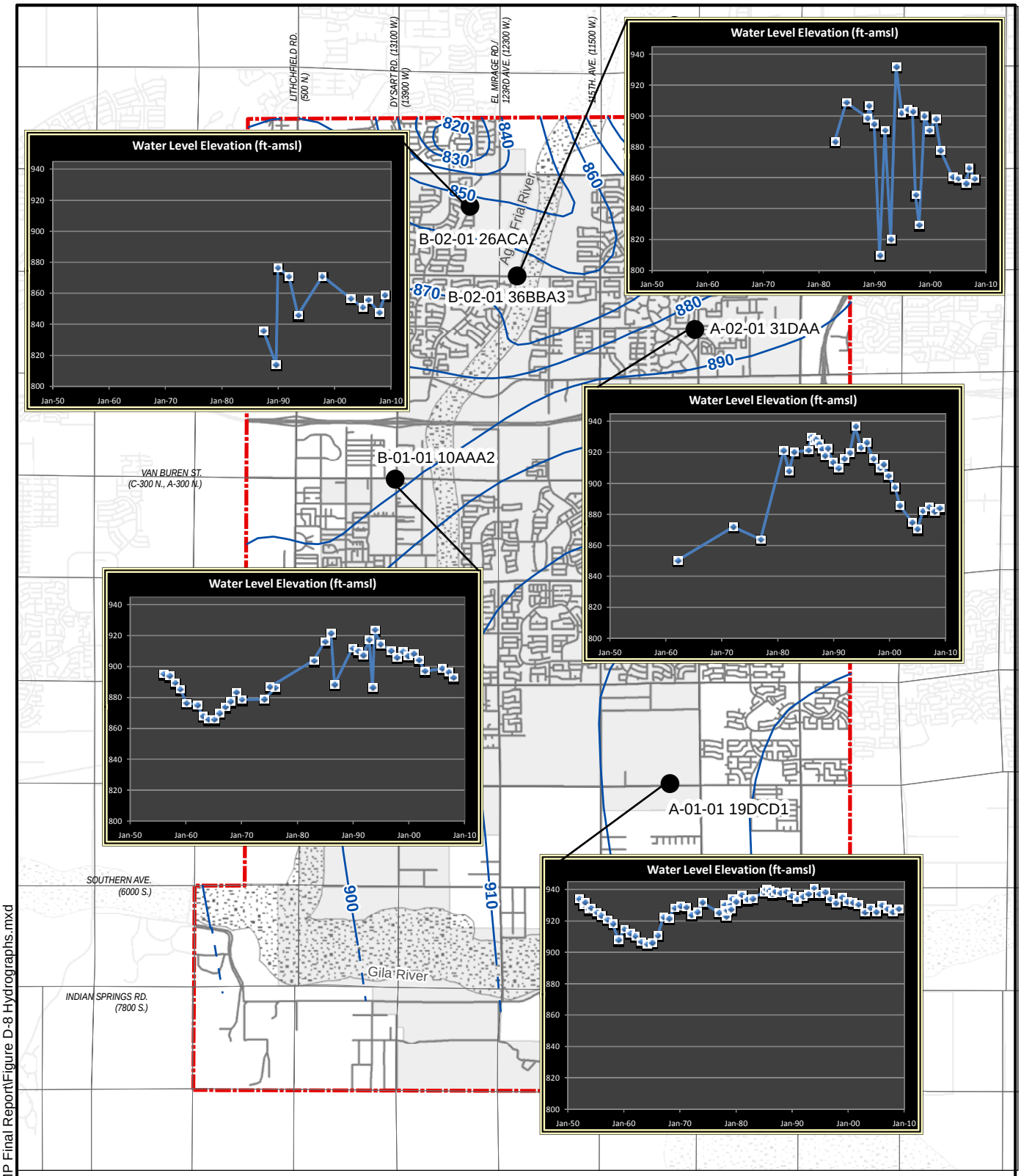
Trends in groundwater elevations over time were also evaluated using data from ADWR groundwater monitoring site index wells (ADWR, 2009b). Data was obtained from five monitoring wells for which a long duration of monitoring data was available. Monitoring wells located within the northern portion of the study area were favored since a larger number of the City's supply wells are present in this area. Monitoring data were available as far back as the early 1950's.

Water levels from each of the monitoring wells exhibited similar trends over time (Figure D-8). A period of water level decline was apparent from the early 1950's to the mid 1960's. This appears to correspond to a long historical drought period extending from 1942 to 1964 (USGS, 2005). Water levels then increased from the mid 1960's to the mid 1990's, which corresponded to a wetter than normal period extending from 1965 to 1998 (USGS, 2005). Since 1998, water levels have exhibited a general decline, though levels may have stabilized in the last few years. The recent decline appears to be a result of the current drought period that began in 1999 (USGS, 2005).

The hydrographs for wells B-02-01 26ACA, B-02-01 36BBA3, and B-01-01 10AAA2 show occasional rapid changes in water from one measurement to the next. These data points are indicative of dates when the wells were actively pumping. Variations in non-pumping water levels are generally greatest within the northern portion of the study area (up to 86 feet at A-02-01 31DAA) and least beneath the southern portion of the study area (36 feet at A-01-01 19DCD1). This attributable to the pumping centers being a greater distance from the primary source of recharge.

D.3.2. Hydraulic Properties

Aquifer transmissivity is a measure of the ability of the aquifer to transmit water to a pumping well. Aquifer transmissivity is an important consideration in evaluation the available water resources since greater transmissivities generally indicate greater production potential. The transmissivity is defined as the product of the thickness and the hydraulic conductivity of the aquifer. The thickness and the hydraulic conductivity of the basin-fill sediments underlying the study area were evaluated individually as factors affecting the potential for future water supplies.



N

0 0.5 1

Miles

Elevation (ft-amsl)

Date

Explanation

A-01-01 19AAA — ADWR well identification

900 — Water level contour (feet above mean sea level) Dashed where inferred, contour interval = 10 feet Source: ADWR water level database --- water levels measured between November 2008 and March 2009

Study area

CITY OF AVONDALE, ARIZONA
WATER RESOURCE MASTER PLAN

Hydrographs

MALCOLM PIRNIE

May 2010

FIGURE D-8

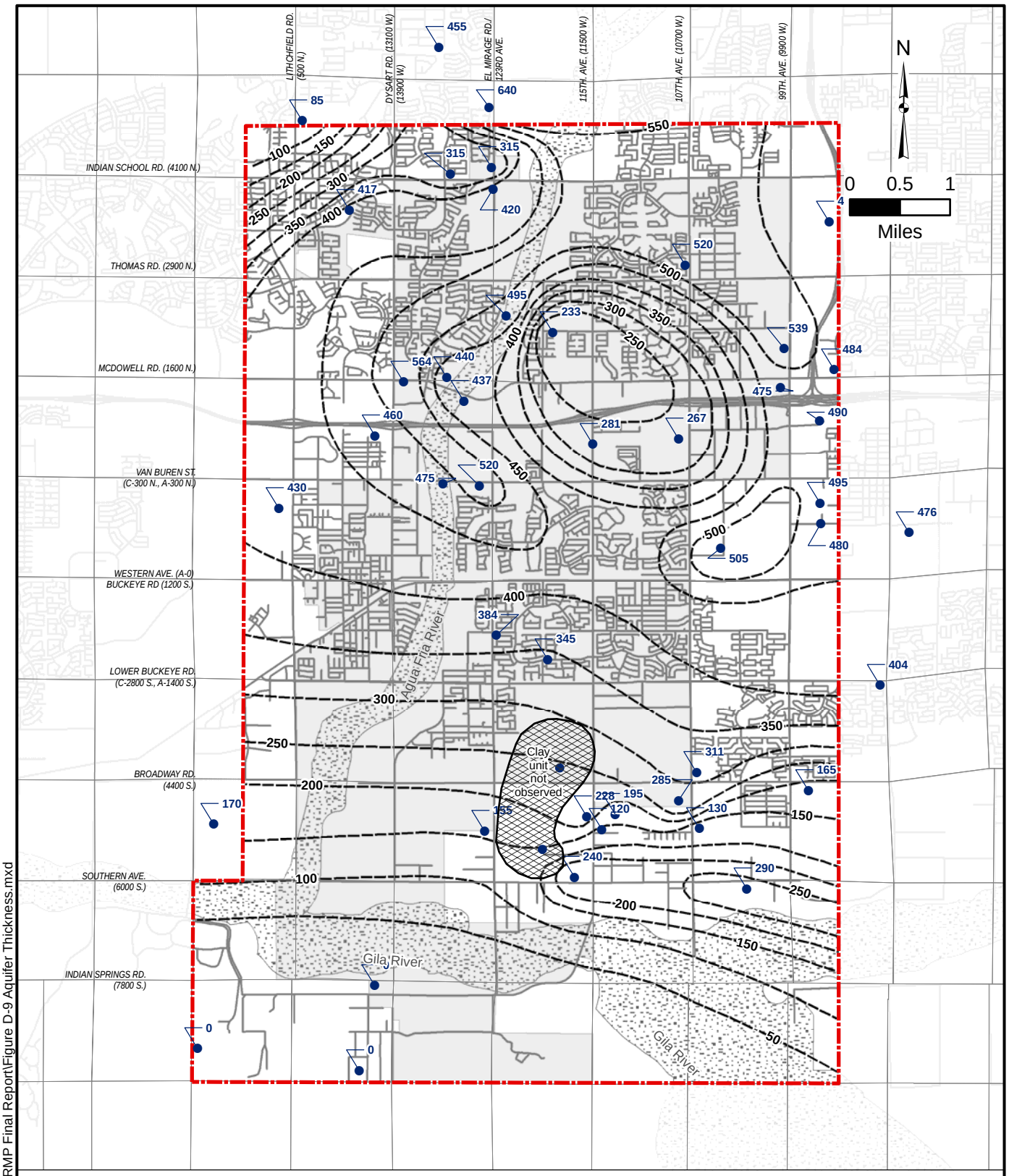
\\phoenix\projects\0864025\GIS\MXDs\WRMP Final Report\Figure D-8 Hydrographs.mxd

An estimated aquifer thickness map was constructed using the groundwater elevation contour map and the depth to the top of the extensive clay map. The aquifer thickness map represents the total saturated thickness of basin-fill sediments that contain significant coarse granular layers (Figure D-9). The aquifer thickness map exhibited a similar pattern to the depth to the top to extensive clay map (Figure D-6). This indicates that the change in the depth to the top of the extensive clay has a greater influence on aquifer thickness than the change in the groundwater elevation. The estimated aquifer thickness is greatest beneath the northern portion of the study area despite the fact the groundwater elevations are lowest in this area. The aquifer is thinnest near the Sierra Estrella, beneath the extreme northwest corner of the study area, and in a small area beneath I-10. The aquifer is also thicker in areas where the extensive clay unit is absent (both identified and unidentified areas). The area where the extensive clay unit is absent was not contoured due to the lack of stratigraphic control.

ADWR maintains a regional groundwater flow model of the Salt River Valley, which represents the most complete study of the regional hydraulic properties of the basin-fill sediments (Correll and Corkhill, 1994). ADWR evaluated hydrogeologic data from aquifer test sites, groundwater contamination sites, specific capacity data from ADWR's Groundwater Site Inventory, and particle size data from the USGS to assign hydraulic properties to the half mile by half mile grid cells in the groundwater flow model (Correll and Corkhill, 1994). Hydraulic conductivities estimated for the UAU within the study area ranged from 7 to 141 feet/day. Hydraulic conductivities were greatest along the Sierra Estrella mountain front, and least in the northern quarter of the study area. Hydraulic conductivities estimated for the MAU ranged from 2.1 to 53 feet/day, with the greatest conductivities along the mountain front, and the smallest conductivities in both northwestern and mid-southeastern portions of the study area. The hydraulic conductivities estimated for the LAU were the least of the three units and ranged from 2 to 24 feet/day. Similar to the MAU, conductivities were greatest along the mountain front and least in the northwestern and mid-southeastern portions of the study area. Graphical depictions of the hydraulic conductivities assigned to the UAU, MAU, and LAU in the groundwater flow model are provided as Figures D-10 through D-12.

Aquifer testing data from several of the City's supply wells were also available to characterize the hydraulic properties of the UAU and the upper portion of the MAU. Aquifer testing data were available for City wells 8A, 14, 15, 16, 19, 20, 21, 23, and 24. Hydraulic properties estimated from these aquifer tests are summarized in Table D-1.

The majority of the City wells for which aquifer testing data are available are screened across both the UAU and the upper portion of the MAU. Therefore, the hydraulic properties estimated from these tests are composite values for the two units. Wells 14, 15, 23, and 24, however, are screened across an individual unit. These tests provide a true measure of the hydraulic properties of the respective units. The locations of these



Source

ADWR water level database -- water levels measured between November 2008 and March 2009.

ADWR driller logs

Explanation

200 — **Data point used to estimate aquifer thickness Thickness assumed to be the difference between the top of the extensive clay unit and water table as measured from November 2008 to March 2009**

900 — **Aquifer thickness contour (feet) Contour interval = 50 feet**

Study area

City of Avondale

CITY OF AVONDALE, ARIZONA
WATER RESOURCE MASTER PLAN

Estimated Aquifer Thickness Map

MALCOLM PIRNIE

May 2010

FIGURE D-9

\\phoenix\projects\0864025\GIS\MXDs\WRMP Final Report\Figure D-9 Aquifer Thickness.mxd

tests and resulting estimated hydraulic conductivities are plotted on Figures D-10 through D-12. The conductivities obtained from the regional groundwater flow model were modified to incorporate the aquifer testing information. Hydraulic conductivities summarized in Table D-1 were calculated by dividing the transmissivities estimated from the aquifer tests by the thickness of the respective unit. For wells screened across both the UAU and the upper portion of the MAU, the aquifer thickness was assumed to be the total saturated thickness of UAU and the upper portion of the MAU.

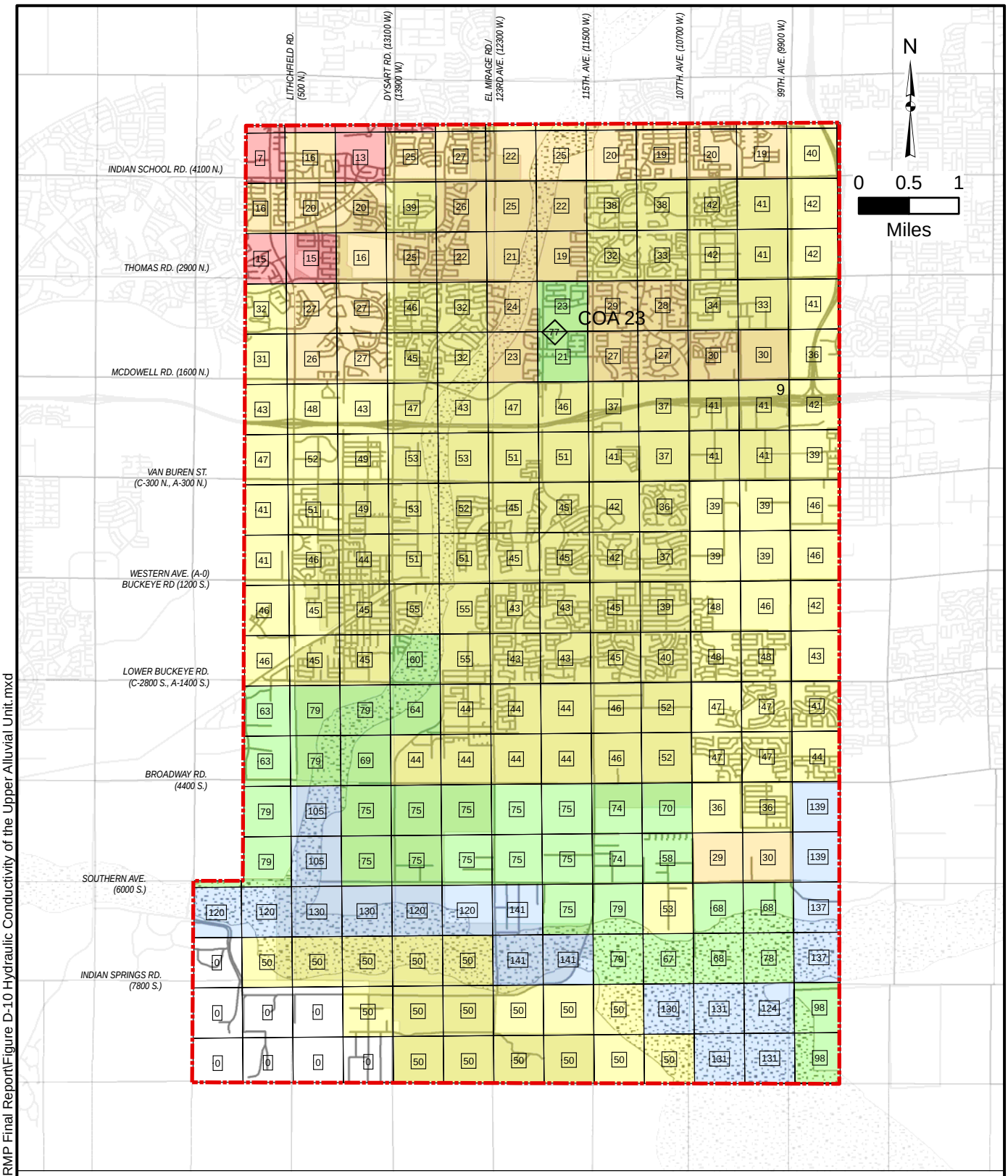
Table D-1:
City of Avondale Aquifer Testing Data

Well	Aquifer	Transmissivity (gpd/ft)	Aquifer Thickness (feet)	Hydraulic Conductivity (feet/day)	Source
8A	UAU & MAU	117,200	503	31	CCA, 2004
14	MAU	3,740		9	RBF, 2002
15	MAU	6,700		6	RBF, 2002
16	UAU & MAU	133,000	461	33	URS, 2005a
19	UAU & MAU	84,800	464	24	URS, 2003
20	UAU & MAU	43,700	631	9	CCA, 2006
21	UAU & MAU	116,400	498	31	AMEC, 2007
23	UAU	142,000	245	77	URS, 2005b
24	MAU	29,513	450	9	AMEC, 2006

D.4. Groundwater Quality

Groundwater quality is an important consideration for well siting since water quality parameters that exceed standards can result in the need for costly, long-term treatment systems that result in increased rates for customers. Common water quality parameters that have historically been problematic for the City were evaluated as a factor affecting the favorability of new well sites. The water quality parameters evaluated included TDS, nitrate, fluoride, arsenic, and the pesticide dibromochlorpropane. Contaminants from several federal Superfund and Water Quality Assurance Revolving Fund (WQARF) sites were also considered. Historical water quality data from the previous Water Resources Master Plan (RBF, 2002) were updated with data from more recent consultant reports and the latest point of entry water quality data available from the City's wells (City of Avondale, 2009).

Primary drinking water regulations are legally enforceable standards that apply to public water systems. Exceedences of the primary drinking water standards require treatment systems to produce drinking water that is safe for human consumption. The maximum allowable concentration for contaminants for in drinking water is defined by its MCL.



Explanation

- Study area
- 15 — Hydraulic conductivity (ft/day) of the Upper Alluvial Unit
- 9 — Hydraulic conductivity (ft/day) of COA well aquifer test

Data Source: ADWR Salt River Valley Model (2008)

- Hydraulic conductivity = 1-15 ft/day
- Hydraulic conductivity = 15.1-30 ft/day
- Hydraulic conductivity = 30.1-55 ft/day
- Hydraulic conductivity = 55.1-100 ft/day
- Hydraulic conductivity = >100 ft/day

CITY OF AVONDALE, ARIZONA
WATER RESOURCE MASTER PLAN

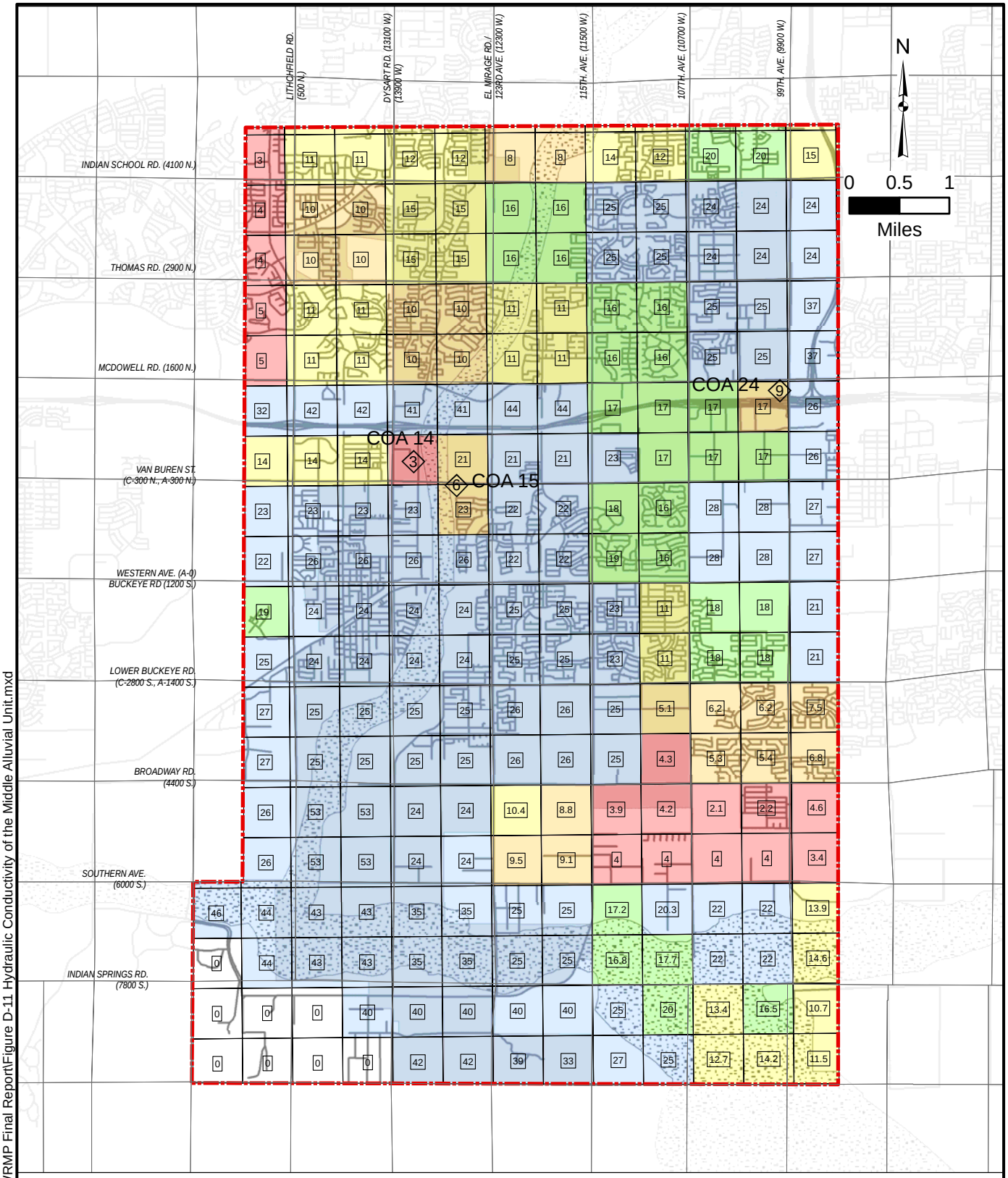
Hydraulic Conductivity of the Upper Alluvial Unit

MALCOLM PIRNIE

May 2010

FIGURE D-10

\\phoenix\projects\0864025\GIS\MXDs\WRMP Final Report\Figure D-10 Hydraulic Conductivity of the Upper Alluvial Unit.mxd



Explanation

- Study area
- 15 — Hydraulic conductivity (ft/day) of the Middle Alluvial Unit
- 9 — Hydraulic conductivity (ft/day) of COA well aquifer test

Data Source: ADWR Salt River Valley Model (2008)

- Hydraulic conductivity = 1-5 ft/day
- Hydraulic conductivity = 5.1-10 ft/day
- Hydraulic conductivity = 10.1-15 ft/day
- Hydraulic conductivity = 15.1-20 ft/day
- Hydraulic conductivity = >20 ft/day

City of Avondale

CITY OF AVONDALE, ARIZONA
WATER RESOURCE MASTER PLAN

Hydraulic Conductivity of the Middle Alluvial Unit

MALCOLM PIRNIE

May 2010

FIGURE D-11

\\phoenix\projects\0864025\GIS\MXDs\WRMP Final Report\Figure D-11 Hydraulic Conductivity of the Middle Alluvial Unit.mxd

Explanation

Study area

15 Hydraulic conductivity (ft/day) of Lower Alluvial Unit

Data Source: ADWR Salt River Valley Model (2008)

Hydraulic conductivity = 0-5 ft/day

Hydraulic conductivity = 5.1-10 ft/day

Hydraulic conductivity = 10.1-15 ft/day

Hydraulic conductivity = 15.1-20 ft/day

Hydraulic conductivity = >20 ft/day

City of Avondale

CITY OF AVONDALE, ARIZONA
WATER RESOURCE MASTER PLAN

Hydraulic Conductivity of the Lower Alluvial Unit

MALCOLM PIRNIE

May 2010

FIGURE D-12

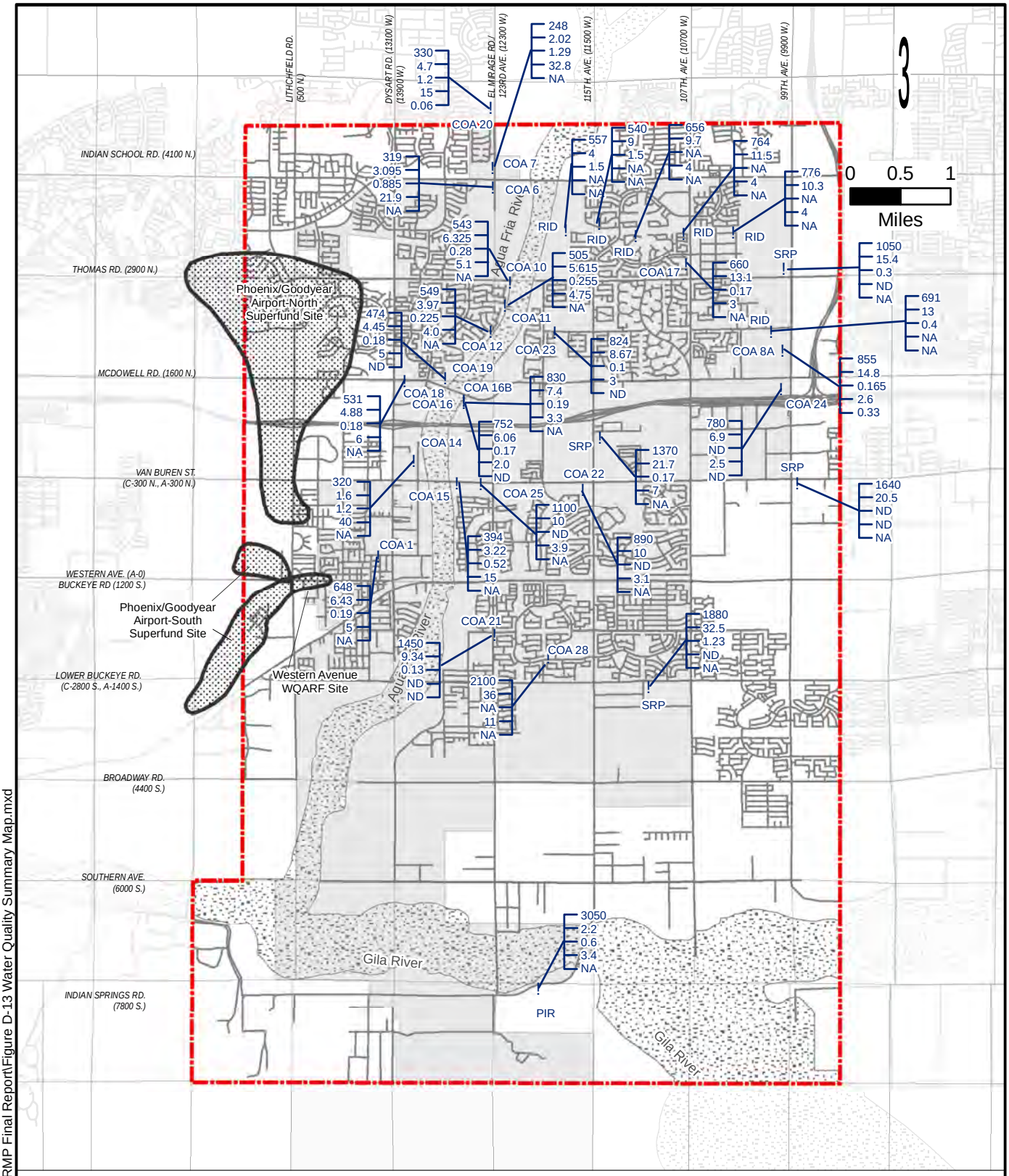
\\phoenix\projects\0864025\GIS\MXDs\WRMP Final Report\Figure D-12 Hydraulic Conductivity of the Lower Alluvial Unit.mxd

The MCL's for the evaluated water quality parameters are 10 mg/L for nitrate, 10 μg/L for arsenic, 4 mg/L for fluoride, and 0.2 μg/L for dibromochloropropane (DBCP). There is no primary drinking water standard for TDS. Secondary drinking water standards are non-enforceable guidelines for contaminants that may cause adverse cosmetic or aesthetic effects. Exceedences of the secondary drinking water standards may require treatment to produce drinking water that is not objectionable to consumers. The secondary treatment standard for TDS is 500 mg/L.

Water quality data from supply wells in the study area are presented on Figure D-13. Concentration of TDS, nitrate, fluoride, arsenic, and DBCP are provided for each well. All water quality data are from the past 10 years. TDS concentrations ranged from 248 to 3,050 mg/L. Only 19 percent of the wells exhibited concentrations less than the secondary standard of 500 mg/L, and 25 percent of the wells exhibited concentration greater than 1,000 mg/L. TDS concentration tends to be greatest in southern portion of the study area where few data points are available. Nitrate concentrations ranged from 1.6 to 36 mg/L. 38 percent of the wells exhibited nitrate concentrations that were equal to or exceed the primary drinking water MCL of 10 mg/L. Arsenic concentrations ranged from non-detect to 32.8 μg/L. 19 percent of the wells for which arsenic concentrations are available exceeded the primary drinking water MCL of 10 μg/L. Fluoride concentrations ranged from non-detect to 1.5 mg/L. None of the wells exceeded the primary drinking water MCL of 4 mg/L. Fluoride concentrations do not appear to be an issue in the study area. Water quality data for DBCP was only available for seven of the wells. Of the seven wells, two exhibited detectable concentrations, and one exceeded the primary drinking water standard of 0.2 μg/L. DBCP may be a concern in the study area; however, its occurrence and extent is currently not well understood.

Several sites with contaminated groundwater also exist within the study area. A federal Superfund site exists at the Phoenix/Goodyear Airport (PGA). The site has been divided into two separate project areas referred to the PGA North Superfund site and the PGA South Superfund site. The primary groundwater contaminants of concern at these two sites are trichloroethene and perchlorates. The Western Avenue Site is WQARF site located immediately east of the PGA South Superfund site. The primary groundwater contaminant of concern at this site is tetrachloroethene. Estimated plume boundary maps for each of the three contaminant sites were obtained from the ADEQ (ADEQ, 2009a, ADEQ, 2009b, ADEQ, 2009c). The estimated plume boundaries are depicted on Figure D-13.

The West Van Buren WQARF site also lies within close proximity of the study area. Contaminants of concern in groundwater include tetrachloroethene, trichloroethene, dichloroethene, and chromium. The plume associated with the West Van Buren site is very large, extending east to west for approximately eight miles along the south side of Interstate 10 (not shown). Although the western edge of the plume is approximately two



Superfund Site Programs

WQARF:
Western Avenue Site

Superfund:
Phoenix/Goodyear Airport-North

Phoenix/Goodyear Airport-South

Major Contaminants:
Tetrachloroethene (~60-110 feet below land surface)

Trichloroethene, Perchlorates (~70-130 feet below land surface)

Trichloroethene, Chromium (~0-360 feet below land surface)

Explanation

WELL OWNERS

COA = City of Avondale
SRP = Salt River Project
RID = Roosevelt Irrigation District
PIR = Phoenix International Raceway

Study Area

292 --- Total Dissolved Solids (mg/L)
2.6 --- Nitrate as N (mg/L)
1.0 --- Flouride (mg/L)
5.5 --- Arsenic (ug/L)
0.2 --- Dibromochloropropane (ug/L)

NA = not analyzed
ND = not detected
Water quality data from the period 2000 through 2009

City of Avondale

CITY OF AVONDALE, ARIZONA
WATER RESOURCE MASTER PLAN

Water Quality Summary Map

MALCOLM PIRNIE

May 2010

FIGURE D-13

\\phoenix\projects\0864025\GIS\MXDs\WRMP Final Report\Figure D-13 Water Quality Summary Map.mxd

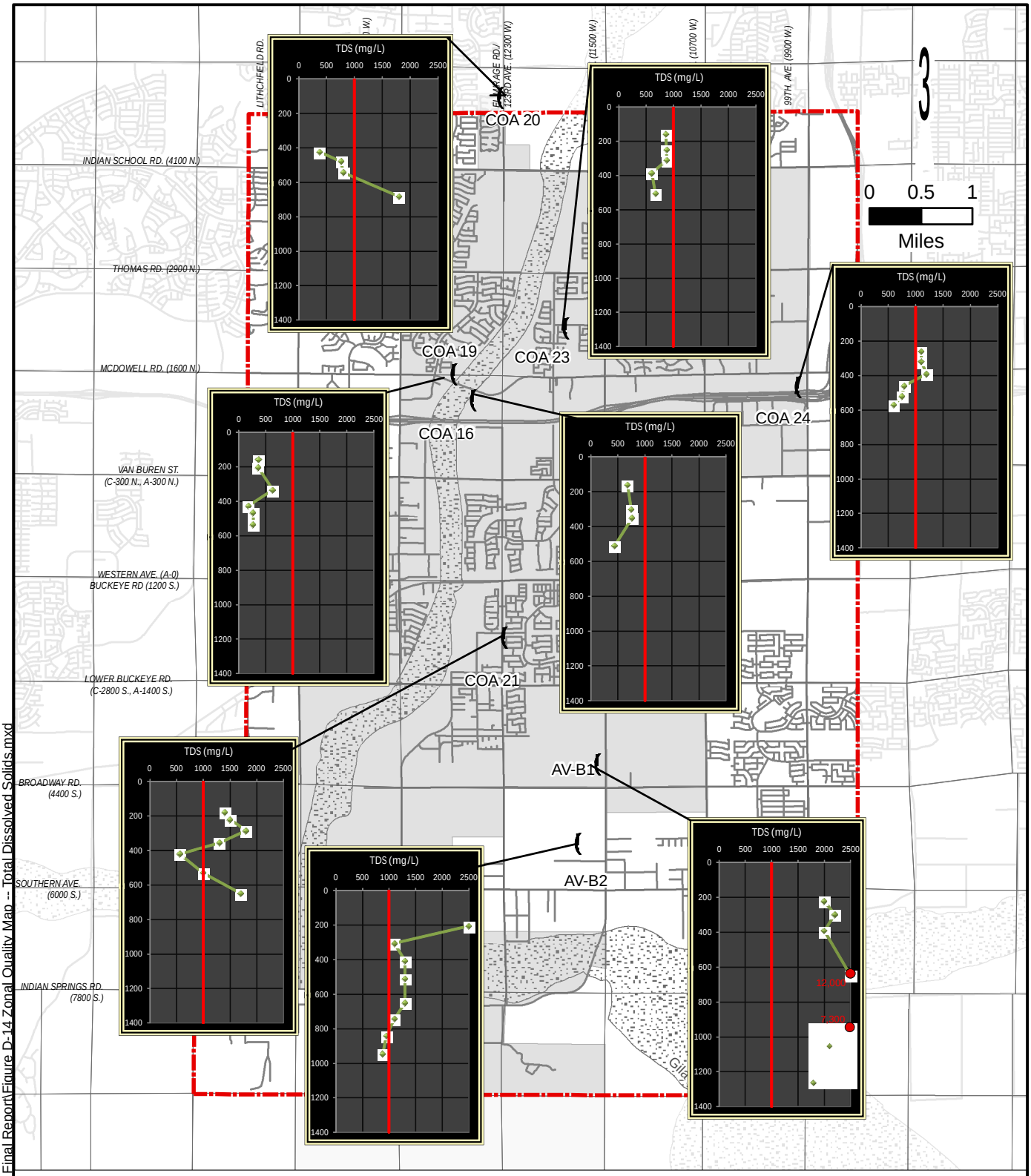
and half miles east of the study area, the potential exists for the plume to be drawn into the study area in the future. Locations near any of the contaminant plumes should not be considered for potential new well sites.

The quality of the groundwater underlying the study area varies with depth. Evaluation of the vertical distribution of the principal water quality parameters is valuable since it will allow the quality of water produced from future wells to be improved by optimizing the depth intervals at which new wells are screened. Zonal water quality data collected from several of the City's well at the time of their installation were compiled to characterize how water quality changes with depth. Zonal water quality data were available for City wells 16, 19, 20, 21, 23, and 24 and for City borings AV-B1 and AV-B2. Graphs of water quality versus depth were prepared for the principal water quality parameters including TDS (Figure D-14), nitrate (Figure D-15), arsenic (Figure D-16), and fluoride (Figure D-17). Data points represent the mid-point of the sampled depth interval. Trends identified from the zonal water quality data are described in the following section.

TDS concentrations changed little at depths above 600 feet bgs. The exceptions are at the AV-B2 boring location where a peak in concentrations was observed at the 195 to 215-foot depth interval and the COA 21 location where a peak was observed at the 260 to 310-foot depth interval. Below 600 feet bgs, TDS concentrations tended to increase, with the exception of the AV-B2 location. Though general patterns in TDS concentrations with depth were observed, the pattern appeared to vary somewhat at different locations in the study area. Trends in nitrate concentrations were more consistent. Nitrate concentrations tended to be greatest at depths shallower than 400 feet bgs and decrease at depths greater than 400 feet bgs. The exceptions were at the COA 23 and AV-B1 locations were nitrate increased slightly with depth. The greater nitrate concentrations at shallow depths are typically attributed to leaching from agricultural land uses. Arsenic concentrations tended to be greatest at depths between 400 and 600 feet bgs and tended to be relatively low at both lesser and greater depths. Flouride concentrations tended to be very low at shallow depths and increase steadily at depths greater than approximately 300 feet. The increasing trend is most dramatic at the southern end of the study area.

General groundwater quality contour maps were constructed using the data presented in Figure D-13. Although the data points are not strictly correlative since water quality varies with depth and the sampled wells are screened across differing depth intervals, the contour maps are nevertheless able to show general areas where water quality is more favorable.

Contour maps were constructed for TDS (Figure D-18), nitrate (Figure D-19), and arsenic (Figure D-20) since these parameters often exceed primary and secondary standards. DBCP concentrations were not contoured due to the sparseness of available data points.



Sources

AMEC, 2006
AMEC, 2007
CCA, 2006
URS, 2003
URS, 2005a
URS, 2005b

Explanation

Study area

Well with zonal water quality data available

Concentration (mg/L)

Depth (feet bgs)

Total dissolved solids (mg/L)

1,000 mg/L concentration line

City of Avondale

CITY OF AVONDALE, ARIZONA
WATER RESOURCE MASTER PLAN

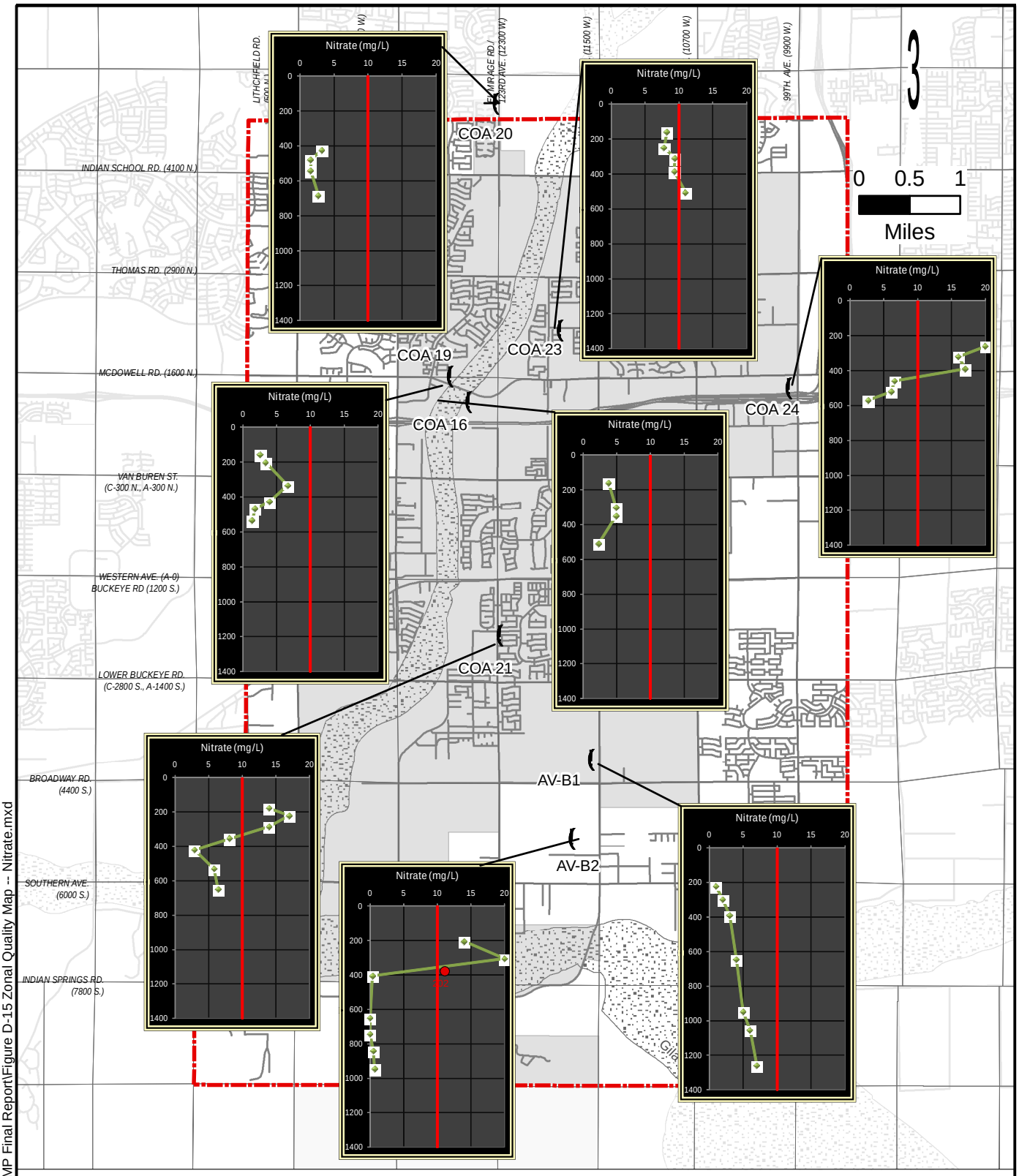
Zonal Quality Map --- Total Dissolved Solids

MALCOLM PIRNIE

May 2010

FIGURE D-14

\\phoenix\projects\0864025\GIS\MXDs\WRMP Final Report\Figure D-14 Zonal Quality Map -- Total Dissolved Solids.mxd



Sources

AMEC, 2006
AMEC, 2007
CCA, 2006
URS, 2003
URS, 2005a
URS, 2005b

Explanation

Study area

Well with zonal water quality data available

Concentration (mg/L)

Depth (feet bgs)

Nitrate as N (mg/L)

10 mg/L concentration line

City of Avondale

CITY OF AVONDALE, ARIZONA
WATER RESOURCE MASTER PLAN

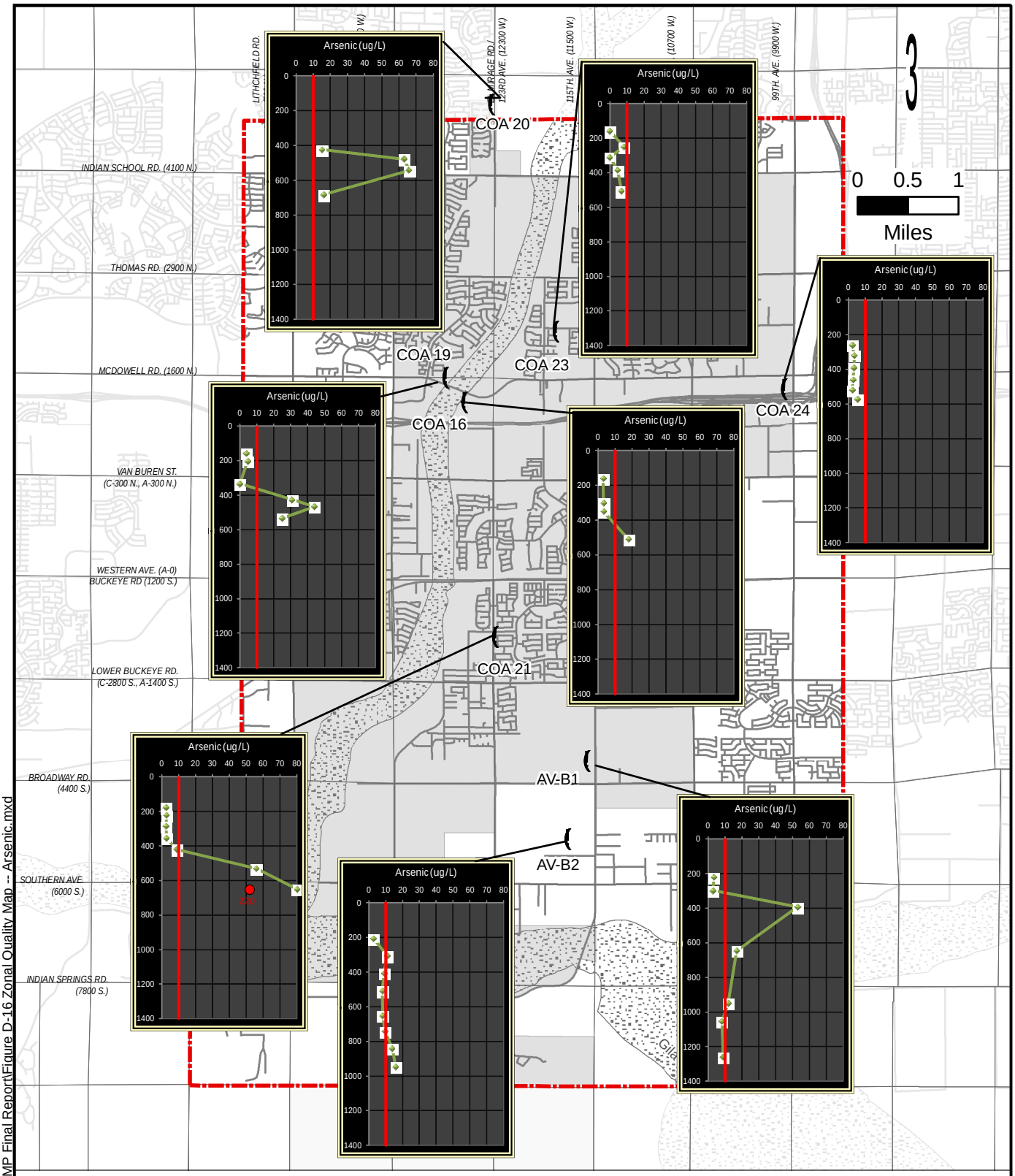
Zonal Water Quality Map --- Nitrate

MALCOLM PIRNIE

May 2010

FIGURE D-15

\\phoenix\projects\086025\GIS\MXDs\WRMP Final Report\Figure D-15 Zonal Quality Map -- Nitrate.mxd



Sources

AMEC, 2006
AMEC, 2007
CCA, 2006
URS, 2003
URS, 2005a
URS, 2005b

Explanation

Study area

Well with zonal water quality data available

Concentration (ug/L)

Depth (feet bgs)

Arsenic (ug/L)

10 ug/L concentration line

CITY OF AVONDALE, ARIZONA
WATER RESOURCE MASTER PLAN

Zonal Water Quality Map --- Arsenic

MALCOLM PIRNIE

May 2010

FIGURE D-16

\\phoenix\projects\0864025\GIS\MXDs\WRMP Final Report\Figure D-16 Zonal Quality Map -- Arsenic.mxd

0 0.5 1
Miles

Sources

AMEC, 2006
AMEC, 2007
CCA, 2006
URS, 2003
URS, 2005a
URS, 2005b

Explanation

Study area

Well with zonal water quality data available

Concentration (mg/L)

Depth (feet bgs)

Fluoride (mg/L)

4 mg/L concentration line

CITY OF AVONDALE, ARIZONA
WATER RESOURCE MASTER PLAN

Zonal Water Quality Map -- Fluoride

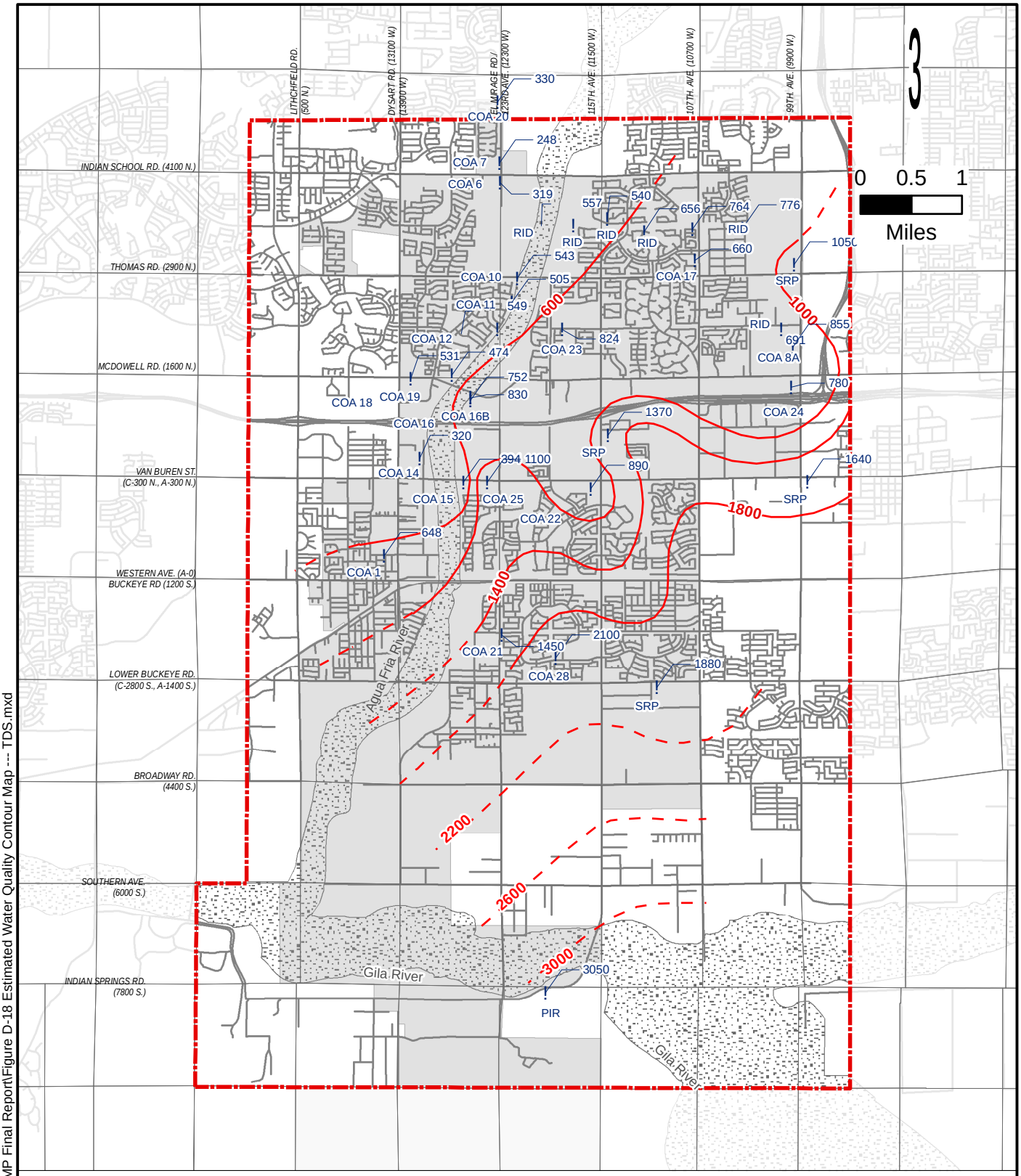
MALCOLM PIRNIE

May 2010
FIGURE D-17

\\phoenix\projects\0864025\GIS\MXDs\WRMP Final Report\Figure D-17 Zonal Quality Map -- Fluoride.mxd

Figure D-18 shows that TDS concentrations generally decrease to the north and west. A few wells west of the Agua Fria River exhibited concentrations less than the secondary standard of 500 mg/L, but most wells in the study area exceeded the standard. The majority of wells south of I-10 and east of the Agua Fria River exhibited concentrations greater than 1,000 mg/L. Nitrate concentration displayed a very similar pattern to TDS concentrations (Figure D-19) with concentrations decreasing to the north and west. Concentrations above the MCL of 10 mg/L were generally limited to areas south of I-10 and east of El Mirage Road. Concentrations were also above 10 mg/L in the far northeastern portion of the study area. Arsenic concentrations exhibited an opposite pattern relative to TDS and nitrate concentrations. Arsenic concentrations tended to be the least in eastern portion of the study area and greatest in the northwestern portion of the study area. The majority of study area exhibited concentrations less than the MCL of 10 μg/L.

A water quality favorability map (Figure D-21) was constructed using combined data from the TDS, nitrate, and arsenic water quality contour maps. Fluoride was excluded as a factor since concentrations within the study area are less than the primary MCL of 4 mg/L. The water quality favorability map shows approximate areas where TDS concentrations are less than 1,000 mg/L, nitrate concentrations are less than 10 mg/L, and arsenic concentrations are less than 10 μg/L. The area highlighted on Figure D-20 represents the most favorable area with respect to water quality for new well sites.



Explanation

292 --- Total Dissolved Solids (mg/L)

NA = not analyzed
ND = not detected

400 — Assumed concentration contour (mg/L)
Contour interval = 400 mg/L
Dashed where inferred

Study Area

CITY OF AVONDALE, ARIZONA
WATER RESOURCE MASTER PLAN

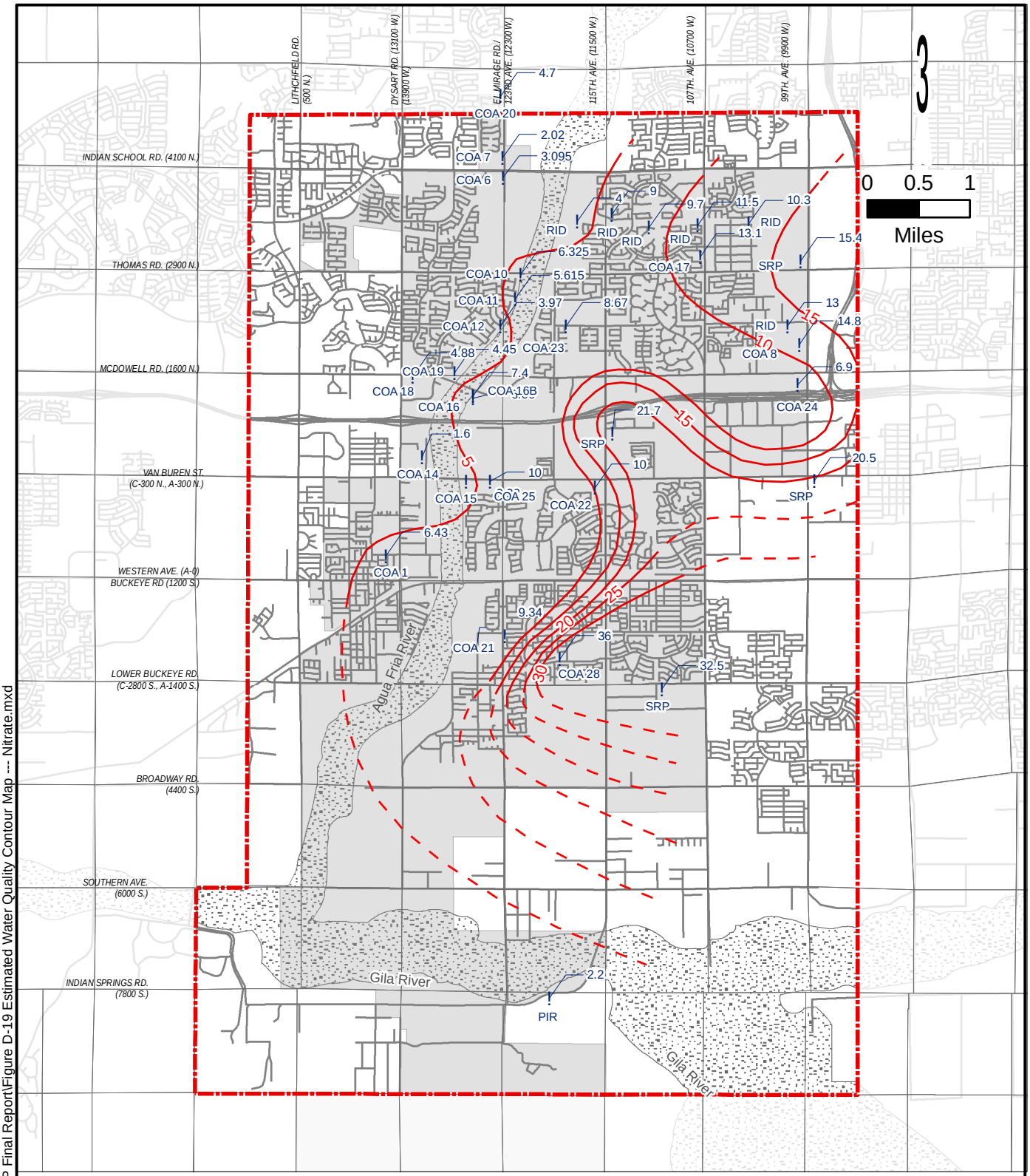
Estimated Water Quality Contour Map - TDS

MALCOLM PIRNIE

May 2010

FIGURE D-18

\\phoenix\projects\0864025\GIS\MXDs\WRMP Final Report\Figure D-18 Estimated Water Quality Contour Map --- TDS.mxd



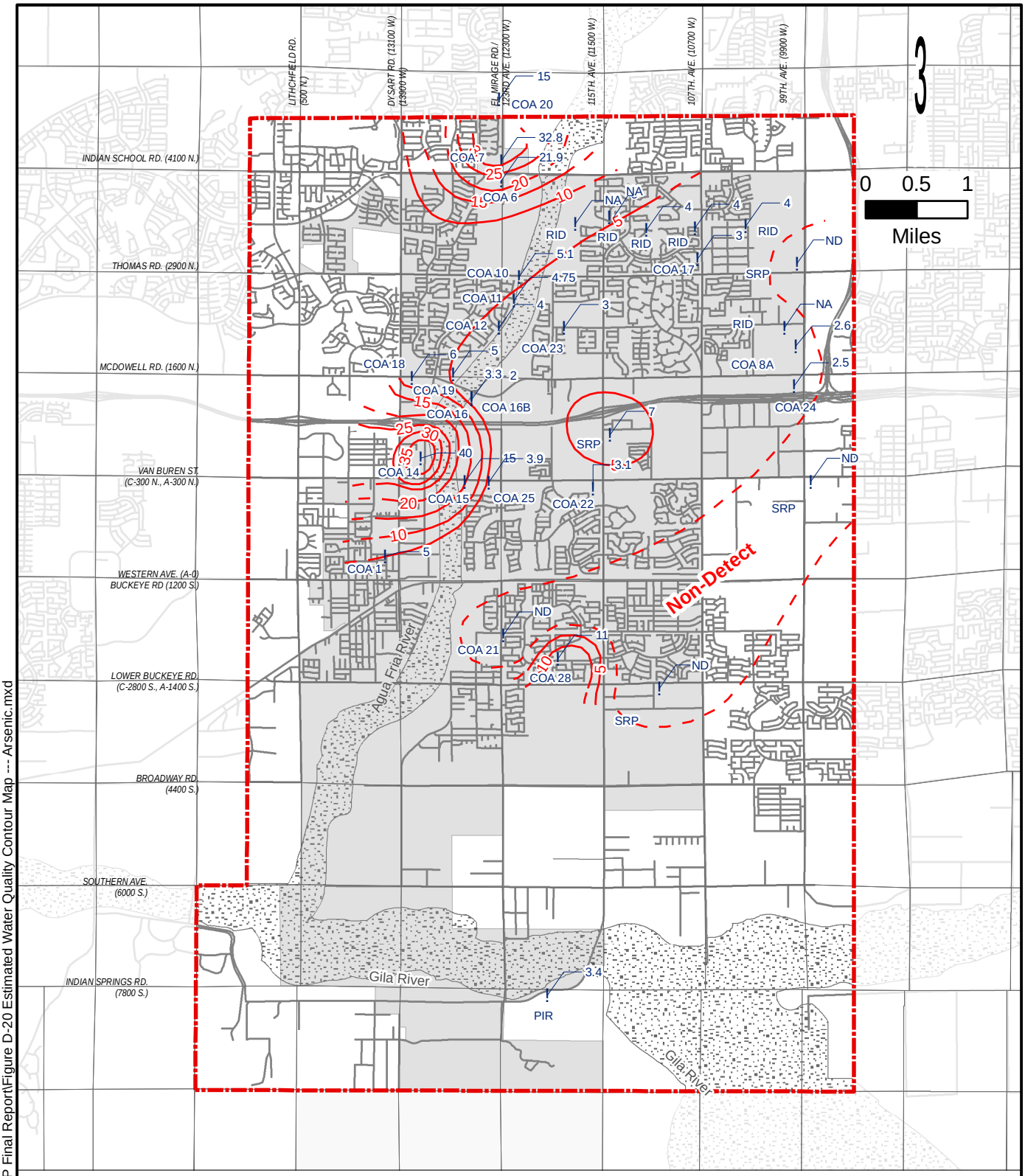
CITY OF AVONDALE, ARIZONA
WATER RESOURCE MASTER PLAN

Estimated Water Quality Contour Map -- Nitrate

MALCOLM PIRNIE

May 2010
FIGURE D-19

\\phoenix\projects\0864025\GIS\MXDs\WRMP Final Report\Figure D-19 Estimated Water Quality Contour Map --- Nitrate.mxd



Explanation

292 --- Arsenic (ug/L)

NA = not analyzed
ND = not detected

400 — Assumed concentration contour (mg/L)
Contour interval = 5 mg/L
Dashed where inferred

Study Area

CITY OF AVONDALE, ARIZONA
WATER RESOURCE MASTER PLAN

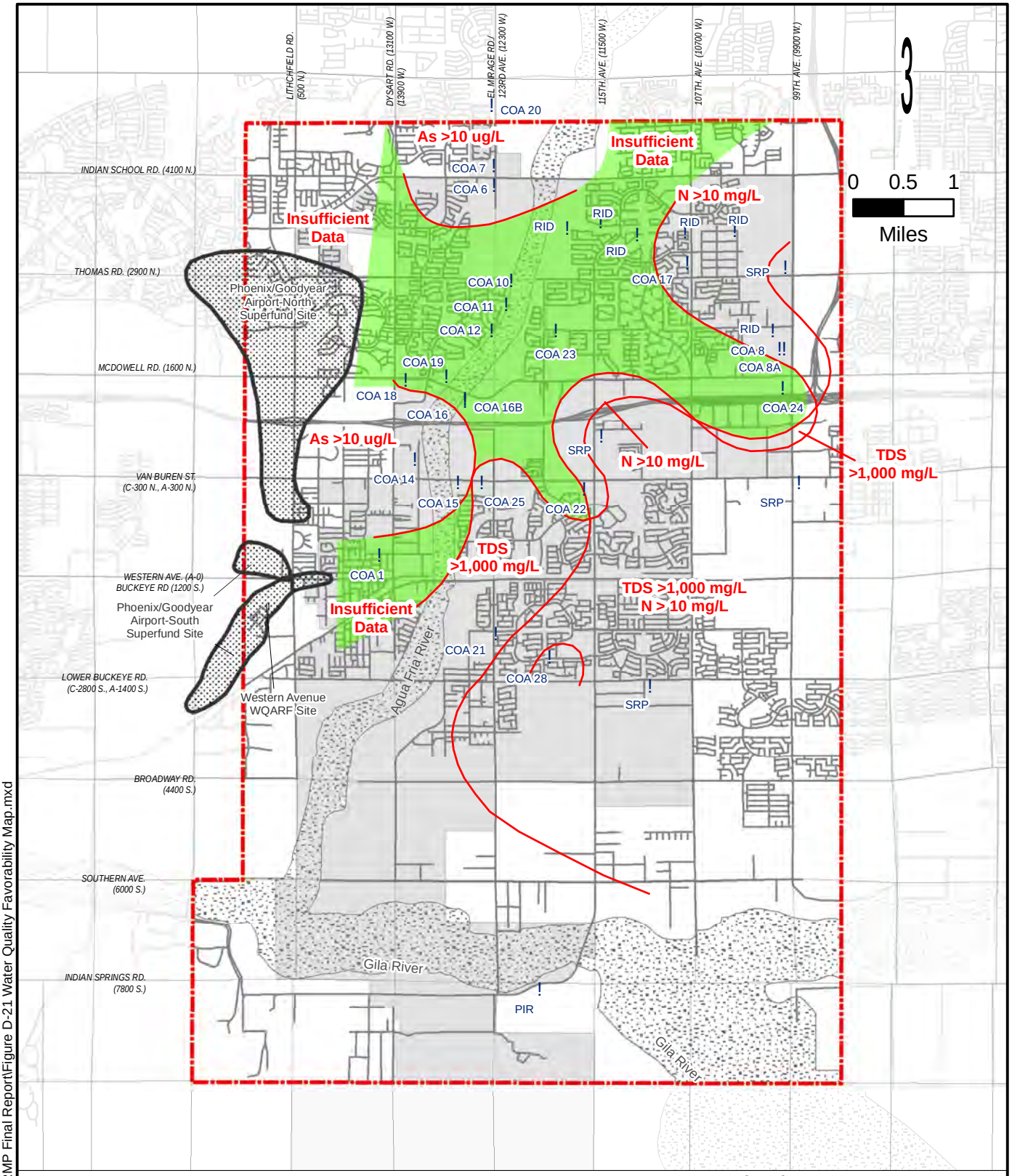
Water Quality Contour Map - Arsenic

MALCOLM PIRNIE

May 2010

FIGURE D-20

\\phoenix\projects\0864025\GIS\MXDs\WRMP Final Report\Figure D-20 Estimated Water Quality Contour Map --- Arsenic.mxd



Superfund Site Programs

WQARF:
Western Avenue Site

Superfund:
Phoenix/Goodyear Airport-North

Phoenix/Goodyear Airport-South

Major Contaminants:
Tetrachloroethene (~60-110 feet below land surface)

Trichloroethene, Perchlorates (~70-130 feet below land surface)

Trichloroethene, Chromium (~0-360 feet below land surface)

Explanation

COA 20 — Water quality data point

Assumed concentration contours:
1000 mg/L total dissolved solids
10 mg/L nitrate
10 ug/L arsenic

Areas with most favorable water quality

Study Area

CITY OF AVONDALE, ARIZONA
WATER RESOURCE MASTER PLAN

Water Quality Favorability Map

MALCOLM PIRNIE

May 2010

FIGURE D-21

\\phoenix\projects\0864025\GIS\MXDs\WRMP Final Report\Figure D-21 Water Quality Favorability Map.mxd

D.5. Prioritizing Existing Wells for Rehabilitation/Re-drilling

Based on the groundwater well water quality evaluation, a review of 11 wells with water quality exceedances was performed in order to select wells for possible rehabilitation or re-drilling:

Well #21 (1450 mg/L TDS)

- Zonal water quality was collected from Well #21
- Well is perforated from 340-440 ft bgs and 480-560 ft bgs
- Zonal TDS concentrations were at or above 1,000 mg/L for the entire depth range from 160-700 feet bgs, except for the 400-440 foot interval
- Due to the consistently poor TDS quality with depth, it is unlikely that TDS concentrations in Well #21 will be improved by packering or re-drilling
- Nitrate exceedances above 310 feet bgs and arsenic exceedances below 500 feet bgs, which further limits targeting other depth intervals
- Well #21 is located to the south where water quality is consistently poorer.

Well #25 (1100 mg/L TDS)

- Well #25 is approximately midway between Wells #16, #19, and #21, which have zonal water quality data available.
- Well #25 is perforated from 340-420 ft and 440-540 ft
- Zonal TDS concentrations in Wells #16, #19, and #21 are all relatively consistent with depth suggesting that it is unlikely that TDS concentrations in Well #25 will be improved by packering off intervals, or redrilling to different depths

Well #8A (14.6 mg/L nitrate)

- Well #8A is located near Well #24, which has zonal water quality data available; #8A is reported to have zonal quality, but that data was not available for this report
- Well #8A is perforated from 289-635 feet bgs
- Well #24 exceeds nitrate MCL above 400 feet bgs, but no exceedances below 400 feet bgs
- Well #24 also has acceptable TDS and arsenic concentrations below 400 feet bgs
- Well #8A is a candidate for puckering off upper perforated intervals to improve nitrate concentrations
- Reduction in capacity should be expected depending on how much of the wells is puckered off

Well #17 (11.3 mg/L nitrate)

- Well #17 is located midway between Wells #23 and #24, which have zonal water quality data available
- Well #17 is perforated from 460-670 feet bgs
- Well #24 has exceedances of nitrate concentrations above 400 feet bgs and no observed exceedances below 400 feet; Well #17 has relatively consistent nitrate concentrations with depth
- Since Well #17 is already only perforated at deep intervals, it is unlikely that packering off intervals or redrilling to different depths will improve nitrate concentrations

Wells #22 and #25 (10 mg/L nitrate)

- Well #22 and #25 are located in close proximity to each other and have similar perforated intervals
- Wells #22 and #25 are located midway between Wells #16 and #21, which have zonal water quality data available
- Well #22 is perforated from 300-420 ft bgs and 440-560 ft bgs: Well #25 is perforated from 340-420 ft bgs and 440-540 ft bgs
- Well #21 has exceedances of nitrate above 300 feet bgs, but no exceedances below 300 feet bgs; Well #16 has consistent nitrate concentration width depth with no exceedances
- Nitrate concentrations might be improved by packering off upper perforated intervals; however, exceedances of arsenic concentrations occur below 400 feet bgs in Well #16 and #21
- Packering off upper intervals may degrade arsenic concentrations

Well #20 (410 µg/L arsenic)

- Well #20 has zonal water quality data available; however, there is no zonal data shallower than 400 feet bgs
- Well #20 is perforated from 299-570 ft bgs and 590-800 ft bgs
- All zonal quality samples from this well exceed 10 µg/L; however no samples exist shallower than 400 feet, and zonal arsenic concentrations in other wells tend to be improved shallower than 400 feet bgs
- Packering off deeper portions of the perforated interval might improve arsenic concentrations; however, current zonal arsenic data is insufficient to support this conclusion
- There are no exceedances of nitrate or TDS shallower than 400 feet bgs at surrounding well location

Wells #6 and #7 (18.45 and 32.8 µg/L arsenic, respectively)

- Wells #6 and #7 are located in close proximity to each other and have similar perforated intervals
- Well #6 and #7 are located near Well #20, which has zonal water quality data; however, no zonal data exists for depths shallower than 400 feet bgs
- Well #6 is perforated from 364-604 feet bgs; Well #7 is perforated from 320-520 feet bgs
- All zonal arsenic samples from Well #20 exceed 10 µg/L; however, arsenic tend to be improved at depths shallower than 400 feet at other well locations
- It may be possible to improve arsenic concentrations in Wells #6 and #7 by packering off deeper intervals or redrill to shallower depths, but current zonal arsenic data is insufficient to support this conclusion
- There are no exceedances of nitrate or TDS shallower than 400 feet bgs at surrounding well location

Wells #14 and #15 (15 µg/L Arsenic)

- Wells #14 and #15 are located in close proximity to each other and have similar screened intervals (Well #14 is inactive but has historically had high arsenic)
- Wells #14 and #15 are midway between Wells #16, #19, and #21, which have zonal water quality data available
- Well #15 has a perforated interval from 370-530 ft bgs: Well 14 has a perforated interval from 370-550 ft bgs
- Zonal arsenic concentrations tend to exceed 10 µg/L below approximately 400 feet bgs in Wells #16, #19, and #21, but do not exceed shallower than 400 feet bgs
- Since most of perforated interval is below the 400 foot depth, it is unlikely that packering intervals will improve water quality; however, redrilling Wells #14 and #15 to shallower depths may be possible to improve arsenic concentrations
- There are no exceedences of nitrate or TDS at depths shallower than 400 feet bgs in Wells #16 and #19; however, Well #21 has nitrate exceedances at shallow depths and TDS exceedances at all depths. The presence of nitrates at shallow depths might be a concern.

Modifying existing wells would take advantage of existing infrastructure already in place, reducing costs incurred by the City. Based on this hydrogeologic evaluation of existing wells, three productions wells (Wells #1, #8A, and #14) were identified as potential rehabilitation/re-drill candidates:

- **Well #1** - City personnel indicated that Well #1 may have been taken off line due to its proximity to the Western Avenue Water Quality Assurance Revolving Fund (WQARF) groundwater contamination site and possibly due to high nitrate

concentrations. Recent data from the Western Avenue WQARF site indicates that the groundwater sampled at the sites monitor wells are below the MCL for the contaminant of concern, perchloroethene, therefore this well may be reactivated after appropriate assessment and rehabilitation.

- **Well #8A -** Well #8A has nitrate at approximately 15 mg/L. Zonal, depth specific water quality sampling from nearby Well #24 indicates nitrate exceeds the MCL above a depth of 400 feet with no exceedances below 400 feet. Well # 8A is screened from 289 feet to 635 feet. This information suggests that that the upper 50 to 100 feet of screen in Well #8A could be sealed off to isolate the higher nitrate zones and reduce overall concentrations. Well # 8A has a reported production rate of 3000 gpm. Such a modification would reduce the production of this well, but it would still likely produce in excess of 1000 gpm.
- **Well #14 -** This well may be a candidate for re-drilling to target better water quality at shallower depths as a non-treatment alternative for providing additional water supply. Well #14 has high arsenic at approximately 0.015 mg/L. Zonal water quality sampling results from other wells in the general area (Wells #16, #19, and #21) suggest that drilling a new well and screening higher may result in reduced arsenic levels. However, shallower levels of the aquifer may have higher concentrations of nitrate and possibly TDS; therefore, an exploratory boring with a comprehensive zonal sampling program is recommended prior to construction of a replacement well for Well #14.

D.6. References

AMEC Earth and Environmental, Inc. 2006. Hydrogeologic Report City of Avondale Production well No. 24, Maricopa County, Arizona. Tempe, Arizona.

AMEC Earth and Environmental, Inc. 2007. Hydrogeologic Report City of Avondale Production Well No. 21, Maricopa County, Arizona. Tempe, Arizona.

Anderson, T.W, Freethey G.W., and Tucci, P. 1992. Geohydrology and Water Resources of Alluvial Basins in South-Central Arizona and Parts of Adjacent States. U.S. Geological Survey Professional Paper 1406-B. Washington.

Arizona Department of Environmental Quality 2009b. Phoenix Goodyear Airport South EPA NPL Site Estimated Plume Boundary. ADEQ GIS and Datat Management Unit. Phoenix, Arizona.

Arizona Department of Environmental Quality. 2009a. Phoenix Goodyear Airport North EPA NPL Site Estimated Plume Boundary. ADEQ GIS and Data Management Unit. Phoenix, Arizona.

Arizona Department of Environmental Quality. 2009a. Western Avenue PCE WQARF Site Estimated Plume Boundary. ADEQ GIS and Data Management Unit. Phoenix, Arizona.

Arizona Department of Water Resources. 2009a. Arizona Department of Water Resources Online Well Registry Data. Arizona Department of Water Resources. Phoenix, Arizona. Accessed August 2009.

Arizona Department of Water Resources. 2009b. Arizona Department of Water Resources Online Groundwater Site Inventory Database and Automated Groundwater Monitoring Sites. Phoenix, Arizona. Accessed August 2009.

Brown, J.G., and Pool, D.R. 1989. Hydrogeology of the Western Part of the Salt River Valley Area, Maricopa County, Arizona. Water-Resources Investigation Report 88-4202. Department of the Interior. U.S. Geological Survey.

Clear Creek Associates. 2004. Completion Report for Avondale Well 8A. Avondale Arizona. Phoenix, Arizona.

Clear Creek Associates. 2006. Completion Report for Avondale Well No. 20. Avondale, Arizona.

Corkhill, E.F., Corell, S., Hill, B.M., and Carr, D.A. 1993. A Regional Groundwater Flow Model of the Salt River Valley – Phase 1: Phoenix Active Management Area Hydrogeologic Framework and Basic Data Report. Modeling Report No. 6. Arizona Department of Water Resources. Phoenix, Arizona.

Correll, S.W. and Corkhill, E.F. 1994. A Regional Groundwater Flow Model of the Salt River Valley – Phase 2: Phoenix Active Management Area Numerical Model, Calibration, and Recommendations. Modeling Report No. 8. Arizona Department of Water Resources. Phoenix, Arizona.

Geological Survey Professional Paper 1406-B. United States Government Printing Office, Washington.

Hammet, B.A., and Herther, R.L. 1993. Map Showing Groundwater Conditions in the Phoenix Active Management Area: Maricopa, Pinal, and Yavapai Counties, Arizona --1992. Arizona Department of Water Resources. Phoenix, Arizona.

Rascona, S.J. 2004. Map Showing Groundwater Conditions in the Phoenix Active Management Area: Maricopa, Pinal, and Yavapai Counties, Arizona – Nov. 2002 – Feb. 2003. Arizona Department of Water Resources. Phoenix, Arizona.

RBF Consulting. 2002. City of Avondale Water Resources Master Plan. Phoenix, Arizona.

URS. 2005a. Final Report Drilling, Installation, and Testing of City of Avondale. Phoenix, Arizona.

URS. 2005b. Final Drilling, Installation, and Testing of City of Avondale Well No. 23, Avondale, Arizona. Phoenix, Arizona.

USGS. 2005. *Hydrologic Conditions in Arizona During 1999-2004:* A Historical Perspective. U.S. Geological Survey Fact Sheet 2005-3081. Tucson, Arizona.

THIS PAGE INTENTIONALLY LEFT BLANK

E. Alternative Calculations

THIS PAGE INTENTIONALLY LEFT BLANK

Storage Requirements Calculations

Parameters	2010	2015	2020	Build-out
Average Day (mgd)	12.9	15.2	19.1	26.4
Maximum Day (mgd)	21.3	25.1	31.5	43.6
Peak Hour (mgd)	33.4	39.4	49.5	68.4
Fire Flow (MG) 3500 gpm for 4 hours	0.8	0.8	0.8	0.8
Total Production Capacity (mgd)	28.4	33.4	42.0	58.1
Existing Storage Capacity	15.5	15.5	15.5	15.5
Storage Criteria				
Peak Hour Storage (Satisfy 4 hours at peak hour demand with 50% source capacity and 50% storage capacity)	6.4	7.6	9.5	13.1
Fire Flow (Satisfy maximum day and FF with 80% total storage and all sources)	-0.4	-0.7	-1.1	-2.0
Operating Storage (≥20% of maximum day demand)	4.3	5.0	6.3	8.7
Emergency Supply (Satisfy average day with 80% storage volume and 50 % of well supply operated no more than 18 hours)	2.8	3.3	4.2	5.8
Additional Storage Required (MG)	**0**	**0**	**0**	**0**

Well Calculations: Continue to Build Wells (Alternatives 1, 2, and 3)

Parameters	2010	2015	2020	Build-out
Average Day (mgd)	12.9	15.2	19.1	26.4
Maximum Day (mgd)	21.3	25.1	31.5	43.6
Existing Production Capacity[1]	35.7	35.7	39.5	39.5
Production Criteria				
Total Supply (Satisfy maximum day demand with largest well[2] out of service)	31.4	31.4	35.2	35.2
Reliable Supply (Satisfy maximum day demand with all wells operating 18 hours of less)	28.4	33.4	42.0	58.1
Production Capacity Required (MG)	**0.0**	**0.0**	**2.5**	**18.6**
Number of Wells Required[3]	**0**	**0**	**2**	**11**

[1]The existing production capacity was assumed based on the preliminary information provided by the City. The values has since been revised.

[2]The capacity of largest well is determined by Wells #18 and #19. As both wells are operate to blend water, loss of Well #19 would result in the loss of Well #18, for a total capacity loss of 3,000 gpm.

[3]Assumed average well capacity of 1,200 gpm (1.73 mgd)

Well Calculations: Build a Surface WTP (Alternatives 4 and 5)

Parameters	2010	2015	2020	Build-out
Average Day (mgd)	12.9	15.2	19.1	26.4
Maximum Day (mgd)	21.3	25.1	31.5	43.6
WTP Capacity (mgd)	0.0	0.0	10.0	15.0
Existing Production Capacity[1]	35.7	35.7	39.5	39.5
Production Criteria				
Total Supply (Satisfy maximum day demand with largest well[2] out of service)	31.4	31.4	35.2	35.2
Reliable Supply (Satisfy maximum day demand with all wells operating 18 hours of less)	28.4	33.4	38.7	53.1
Production Capacity Required (MG)[3]	**0.0**	**0.0**	**0.0**	**9.1**
Number of Wells Required[4]	**0**	**0**	**0**	**6**

[1] The existing production capacity was assumed based on the preliminary information provided by the City. The values has since been revised.

[2] The capacity of largest well is determined by Wells #18 and #19. As both wells are operate to blend water, loss of Well #19 would result in the loss of Well #18, for a total capacity loss of 3,000 gpm.

[3] Total capacity of On-Projects wells (10.48 mgd) was subtracted from the existing production capacity as Surface WTP already accounts for the total On-Project water that can be used.

[4] Assumed average well capacity of 1,200 gpm (1.73 mgd)

Summary of Capital Unit Costs[1,2]

ITEM	UNITS	COST (Nov. 2009)
CAPITAL COSTS		
Pipelines		
Ductile Iron Pipe		
6"	$/LF	$84
8"	$/LF	$112
10"	$/LF	$140
12"	$/LF	$168
14"	$/LF	$196
16"	$/LF	$224
18"	$/LF	$252
20"	$/LF	$280
24"	$/LF	$336
30"	$/LF	$420
36"	$/LF	$504
Reservoirs (covered)		
0.0 to < 2.5 MG	$/MG	$1,515,156
Booster Pump Stations		
0 to < 7 mgd	$/mgd	$361,571
7 to < 13 mgd	$/mgd	$229,316
13 to < 17 mgd	$/MGD	$190,552
17 to < 25 mgd	$/MGD	$163,770
25 to < 35 mgd	$/MGD	$128,054
Pressure Reducing Valves		
3 to < 6 mgd	$/mgd	$388,641
6 to < 15 mgd	$/mgd	$154,403
New Production Wells/Redrilling	$/well	$2,192,091
Wellhead Rehabilitation	$/well	$1,000,000
Arsenic Treatment	$/mgd	$1,301,014
TDS Treatment	$/well	$4,411,460
Water Treatment Plant (15 mgd)	$/mgd	$3,082,576

NOTES:

(1) November 2009 Costs (ENR CCI = 8,592).

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

Summary of O&M Unit Costs[1]

ITEM	UNITS	COST (Nov. 2009)
O&M COSTS		
Pipelines	$/mile/year	$3,738
Recharge Basin	$/1,000 gal	$0.06
CAWCD Recharge	$/AF	$23
NAUSP Recharge	$/AF	$24
Wheeling Fee	$/AF	$23
Reservoir	$/yr-each	$7,476
Booster Pump Station		
Power	$/kWh	$0.08
Maintenance		3% of capital
Pressure Reducing Valves		1% of capital
Production Well	$/1,000 gal	$0.21
Arsenic Treatment	$/1,000 gal	$0.55
TDS Treatment	$/1,000 gal	$0.85
Water Treatment Plant	$/1,000 gal	$0.71

NOTES:

(1) November 2009 Costs (ENR CCI = 8,592).

Present Worth Assumptions

Discount Rate	**6%**
Term	**20**

Alternative 1: Continue to Build Wells East of Dysart Road
(No Additional Groundwater Treatment)

ITEM	QUANTITY	UNITS	UNIT COST	COST[1]
CAPITAL COSTS				
Pipelines				
6"	4,825	LF	$ 84	$ 405,300
8"	6,946	LF	$ 112	$ 777,952
10"	0	LF	$ 140	$ -
12"	138,481	LF	$ 168	$ 23,264,808
14"	0	LF	$ 196	$ -
16"	131,416	LF	$ 224	$ 29,437,184
18"	0	LF	$ 252	$ -
20"	4,243	LF	$ 280	$ 1,188,040
24"	33,461	LF	$ 336	$ 11,242,896
30"	0	LF	$ 420	$ -
36"	489	LF	$ 504	$ 246,456
Pressure Reducing Valves				
3 to < 6 mgd	3	each	$ 388,641	$ 1,165,923
6 to < 15 mgd	1	each	$ 154,403	$ 154,403
Reservoirs	0	MG	$ 1,515,156	$ -
Booster Pump Stations				
0 to < 7 mgd	8.4	mgd	$ 361,571	$ 3,037,198
7 to < 13 mgd	12.7	mgd	$ 229,316	$ 2,912,311
13 to < 17 mgd	0	mgd	$ 190,552	$ -
17 to < 25 mgd	0	mgd	$ 163,770	$ -
25 to < 35 mgd	0	mgd	$ 128,054	$ -
Production Wells	13	each	$ 2,192,091	$ 28,497,182
Wellhead Rehabilitation	1	each	$ 1,000,000	$ 1,000,000
Water Treatment Plant	0	mgd	$ 3,082,576	$ -
Arsenic Treatment	0	mgd	$ 1,301,014	$ -
TDS Treatment	0	mgd	$ 4,411,460	$ -
TOTAL CAPITAL COST				$ 103,329,653
O&M COSTS				
Pipelines	60.6	miles	$ 3,738	$ 226,459
Reservoirs	0	each	$ 7,476.38	$ -
Booster Pump Stations				
Power	8,179,347	kwh	$ 0.08	$ 654,348
Maintenance	1	3% of Capital	$ 178,485	$ 178,485
Production Wells	9,636,000	1,000 gallons	$ 0.21	$ 2,046,786
Wellhead Arsenic Treatment	1,812,794	1,000 gallons	$ 0.55	$ 1,001,147
Wellhead TDS Treatment	0	1,000 gallons	$ 0.85	$ -
Water Treatment Plant	0	1,000 gallons	$ 0.71	$ -
Recharge (Avondale Facility)	13,390,225	1,000 gallons	$ 0.06	$ 782,113
Regional Recharge O&M (CAWCD)	6,298	AF	$ 23	$ 144,854
Regional Recharge O&M (NAUSP)	7,410	AF	$ 24	$ 177,840
Wheeling Fees	5,416	AF	$ 23	$ 124,568
TOTAL O&M COST				$ 5,336,600
PRESENT WORTH OF O&M[2]				$ 61,210,377
TOTAL PRESENT WORTH[2]				$ 164,540,030

NOTES:

[1] November 2009 Costs (ENR CCI = 8,592).

[2] 20 Years, 6 Percent Interest.

Alternative 2: Continue to Build Wells Around Avondale Recharge Facility
(No Additional Groundwater Treatment)

ITEM	QUANTITY	UNITS	UNIT COST	COST[1]
CAPITAL COSTS				
Pipelines				
6"	4,825	LF	$ 84	$ 405,300
8"	6,946	LF	$ 112	$ 777,952
10"	0	LF	$ 140	$ -
12"	138,481	LF	$ 168	$ 23,264,808
14"	0	LF	$ 196	$ -
16"	131,416	LF	$ 224	$ 29,437,184
18"	0	LF	$ 252	$ -
20"	4,243	LF	$ 280	$ 1,188,040
24"	33,461	LF	$ 336	$ 11,242,896
30"	0	LF	$ 420	$ -
36"	489	LF	$ 504	$ 246,456
Pressure Reducing Valves				
3 to < 6 mgd	3	each	$ 388,641	$ 1,165,923
6 to < 15 mgd	1	each	$ 154,403	$ 154,403
Reservoirs	0	MG	$ 1,515,156	$ -
Booster Pump Stations				
0 to < 7 mgd	8.4	mgd	$ 361,571	$ 3,037,198
7 to < 13 mgd	12.7	mgd	$ 229,316	$ 2,912,311
13 to < 17 mgd	0	mgd	$ 190,552	$ -
17 to < 25 mgd	0	mgd	$ 163,770	$ -
25 to < 35 mgd	0	mgd	$ 128,054	$ -
Production Wells	13	each	$ 2,192,091	$ 28,497,182
Wellhead Rehabilitation	1	each	$ 1,000,000	$ 1,000,000
Water Treatment Plant	0	mgd	$ 3,082,576	$ -
Arsenic Treatment	0	mgd	$ 1,301,014	$ -
TDS Treatment	0	mgd	$ 4,411,460	$ -
TOTAL CAPITAL COST				$ 103,329,653
O&M COSTS				
Pipelines	60.6	miles	$ 3,738	$ 226,459
Reservoirs	0	each	$ 7,476.38	$ -
Booster Pump Stations				
Power	8,179,347	kwh	$ 0.08	$ 654,348
Maintenance	1	3% of Capital	$ 178,485	$ 178,485
Production Wells	9,636,000	1,000 gallons	$ 0.21	$ 2,046,786
Wellhead Arsenic Treatment	1,812,794	1,000 gallons	$ 0.55	$ 1,001,147
Wellhead TDS Treatment	0	1,000 gallons	$ 0.85	$ -
Water Treatment Plant	0	1,000 gallons	$ 0.71	$ -
Recharge (Avondale Facility)	13,390,225	1,000 gallons	$ 0.06	$ 782,113
Regional Recharge O&M (CAWCD)	6,298	AF	$ 23	$ 144,854
Regional Recharge O&M (NAUSP)	7,410	AF	$ 24	$ 177,840
Wheeling Fees	5,416	AF	$ 23	$ 124,568
TOTAL O&M COST				$ 5,336,600
PRESENT WORTH OF O&M[2]				$ 61,210,377
TOTAL PRESENT WORTH[2]				$ 164,540,030

NOTES:

[1] November 2009 Costs (ENR CCI = 8,592).

[2] 20 Years, 6 Percent Interest.

Alternative 3: Continue to Build Wells Throughut Service Area
(No Additional Groundwater Treatment)

ITEM	QUANTITY	UNITS	UNIT COST	COST[1]
CAPITAL COSTS				
Pipelines				
6"	4,825	LF	$ 84	$ 405,300
8"	7,447	LF	$ 112	$ 834,065
10"	0	LF	$ 140	$ -
12"	132,215	LF	$ 168	$ 22,212,120
14"		LF	$ 196	$ -
16"	131,513	LF	$ 224	$ 29,458,912
18"	0	LF	$ 252	$ -
20"	22,678	LF	$ 280	$ 6,349,840
24"	21,542	LF	$ 336	$ 7,238,112
30"	0	LF	$ 420	$ -
36"	489	LF	$ 504	$ 246,456
Pressure Reducing Valves				
3 to < 6 mgd	0	each	$ 388,641	$ -
6 to < 15 mgd	0	each	$ 154,403	$ -
Reservoirs	0	MG	$ 1,515,156	$ -
Booster Pump Stations				
0 to < 7 mgd	11.86	mgd	$ 361,571	$ 4,288,235
7 to < 13 mgd	9.22	mgd	$ 229,316	$ 2,114,292
13 to < 17 mgd	0	mgd	$ 190,552	$ -
17 to < 25 mgd	0	mgd	$ 163,770	$ -
25 to < 35 mgd	0	mgd	$ 128,054	$ -
Production Wells	13	each	$ 2,192,091	$ 28,497,182
Wellhead Rehabilitation	1	each	$ 1,000,000	$ 1,000,000
Water Treatment Plant	0	mgd	$ 3,082,576	$ -
Arsenic Treatment	0	mgd	$ 1,301,014	$ -
TDS Treatment	5	mgd	$ 4,411,460	$ 21,322,059
TOTAL CAPITAL COST				$ 123,966,573
O&M COSTS				
Pipelines	60.7	miles	$ 3,738	$ 227,059
Reservoirs	0	each	$ 7,476.38	$ -
Booster Pump Stations				
Power	7,767,691	kwh	$ 0.08	$ 621,415
Maintenance	1	3% of Capital	$ 192,076	$ 192,076
Production Wells	9,636,000	1,000 gallons	$ 0.21	$ 2,046,786
Wellhead Arsenic Treatment	1,812,794	1,000 gallons	$ 0.55	$ 1,001,147
Wellhead TDS Treatment	761,594	1,000 gallons	$ 0.85	$ 647,062
Water Treatment Plant	0	1,000 gallons	$ 0.71	$ -
Recharge (Avondale Facility)	13,390,225	1,000 gallons	$ 0.06	$ 782,113
Regional Recharge O&M (CAWCD)	6,298	AF	$ 23	$ 144,854
Regional Recharge O&M (NAUSP)	7,410	AF	$ 24	$ 177,840
Wheeling Fees	5,416	AF	$ 23	$ 124,568
TOTAL O&M COST				$ 5,964,920
PRESENT WORTH OF O&M[2]				$ 68,417,160
TOTAL PRESENT WORTH[2]				$ 192,383,732

NOTES:

[1] November 2009 Costs (ENR CCI = 8,592).

[2] 20 Years, 6 Percent Interest.

Alternative 4: Build a Surface WTP Near Avondale Recharge Facility
(No Additional Groundwater Treatment)

ITEM	QUANTITY	UNITS	UNIT COST	COST[1]
CAPITAL COSTS				
Pipelines				
6"	4,825	LF	$ 84	$ 405,287
8"	7,447	LF	$ 112	$ 834,065
10"	0	LF	$ 140	$ -
12"	119,603	LF	$ 168	$ 20,093,260
14"	0	LF	$ 196	$ -
16"	105,754	LF	$ 224	$ 23,688,912
18"	0	LF	$ 252	$ -
20"	17,608	LF	$ 280	$ 4,930,111
24"	35,042	LF	$ 336	$ 11,774,226
30"	1,600	LF	$ 420	$ 672,000
36"	490	LF	$ 504	$ 247,081
Pressure Reducing Valves				
3 to < 6 mgd	0	each	$ 388,641	$ -
6 to < 15 mgd	0	each	$ 154,403	$ -
Reservoirs	0	MG	$ 1,515,156	$ -
Booster Pump Stations				
0 to < 7 mgd	8.67	mgd	$ 361,571	$ 3,134,823
7 to < 13 mgd	9.82	mgd	$ 229,316	$ 2,251,882
13 to < 17 mgd	0	mgd	$ 190,552	$ -
17 to < 25 mgd	0	mgd	$ 163,770	$ -
25 to < 35 mgd	25	mgd	$ 128,054	SEE WTP
Production Wells	8	each	$ 2,192,091	$ 17,536,727
Wellhead Rehabilitation	1	each	$ 1,000,000	$ 1,000,000
Water Treatment Plant	15	mgd	$ 3,082,576	$ 46,238,641
Arsenic Treatment	0	mgd	$ 1,301,014	$ -
TDS Treatment	0	mgd	$ 4,411,460	$ -
TOTAL CAPITAL COST				$ 132,807,014
O&M COSTS				
Pipelines	55.4	miles	$ 3,738	$ 206,994
Reservoirs	0	each	$ 7,476.38	$ -
Booster Pump Stations				
Power	9,000,434	kwh	$ 0.08	$ 720,035
Maintenance	1	3% of Capital	$ 161,601	$ 161,601
Production Wells	4,161,000	1,000 gallons	$ 0.21	$ 883,840
Wellhead Arsenic Treatment	212,342	1,000 gallons	$ 0.55	$ 117,270
Wellhead TDS Treatment	0	1,000 gallons	$ 0.85	$ -
Water Treatment Plant	5,475,000	1,000 gallons	$ 0.71	$ 3,876,367
Recharge (Avondale Facility)	8,496,544	1,000 gallons	$ 0.06	$ 496,277
Regional Recharge O&M (CAWCD)	0	AF	$ 23	$ -
Regional Recharge O&M (NAUSP)	2,387	AF	$ 24	$ 57,288
Wheeling Fees	5,416	AF	$ 23	$ 124,568
TOTAL O&M COST				$ 6,644,239
PRESENT WORTH OF O&M[2]				$ 76,208,897
TOTAL PRESENT WORTH[2]				$ 209,015,911

NOTES:

[1] November 2009 Costs (ENR CCI = 8,592).

[2] 20 Years, 6 Percent Interest.

Alternative 5: Build a Surface WTP Near 107th Ave. and Roosevelt Rd.
(No Additional Groundwater Treatment)

ITEM	QUANTITY	UNITS	UNIT COST	COST[1]
CAPITAL COSTS				
Pipelines				
6"	4,825	LF	$ 84	$ 405,287
8"	7,447	LF	$ 112	$ 834,065
10"	0	LF	$ 140	$ -
12"	119,603	LF	$ 168	$ 20,093,260
14"	0	LF	$ 196	$ -
16"	105,754	LF	$ 224	$ 23,688,912
18"	0	LF	$ 252	$ -
20"	17,608	LF	$ 280	$ 4,930,111
24"	26,842	LF	$ 336	$ 9,019,026
30"	8,100	LF	$ 420	$ 3,402,000
36"	490	LF	$ 504	$ 247,081
Pressure Reducing Valves				
3 to < 6 mgd	0	each	$ 388,641	$ -
6 to < 15 mgd	0	each	$ 154,403	$ -
Reservoirs	0	MG	$ 1,515,156	$ -
Booster Pump Stations				
0 to < 7 mgd	8.67	mgd	$ 361,571	$ 3,134,823
7 to < 13 mgd	9.82	mgd	$ 229,316	$ 2,251,882
13 to < 17 mgd	0	mgd	$ 190,552	$ -
17 to < 25 mgd	0	mgd	$ 163,770	$ -
25 to < 35 mgd	25	mgd	$ 128,054	SEE WTP
Production Wells	8	each	$ 2,192,091	$ 17,536,727
Wellhead Rehabilitation	1	each	$ 1,000,000	$ 1,000,000
Water Treatment Plant	15	mgd	$ 3,082,576	$ 46,238,641
Arsenic Treatment	0	mgd	$ 1,301,014	$ -
TDS Treatment	0	mgd	$ 4,411,460	$ -
TOTAL CAPITAL COST				$ 132,781,814
O&M COSTS				
Pipelines	55.1	miles	$ 3,738	$ 205,791
Reservoirs	0	each	$ 7,476.38	$ -
Booster Pump Stations				
Power	9,000,434	kwh	$ 0.08	$ 720,035
Maintenance	1	3% of Capital	$ 161,601	$ 161,601
Production Wells	4,161,000	1,000 gallons	$ 0.21	$ 883,840
Wellhead Arsenic Treatment	212,342	1,000 gallons	$ 0.55	$ 117,270
Wellhead TDS Treatment	0	1,000 gallons	$ 0.85	$ -
Water Treatment Plant	5,475,000	1,000 gallons	$ 0.71	$ 3,876,367
Recharge (Avondale Facility)	8,496,544	1,000 gallons	$ 0.06	$ 496,277
Regional Recharge O&M (CAWCD)	0	AF	$ 23	$ -
Regional Recharge O&M (NAUSP)	2,387	AF	$ 24	$ 57,288
Wheeling Fees	5,416	AF	$ 23	$ 124,568
TOTAL O&M COST				$ 6,643,035
PRESENT WORTH OF O&M[2]				$ 76,195,092
TOTAL PRESENT WORTH[2]				$ 208,976,906

NOTES:

[1] November 2009 Costs (ENR CCI = 8,592).

[2] 20 Years, 6 Percent Interest.

Alternative 1: Continue to Build Wells East of Dysart Road
(25 Percent Groundwater Treatment By Volume)

ITEM	QUANTITY	UNITS	UNIT COST	COST[1]
CAPITAL COSTS				
Pipelines				
6"	4,825	LF	$ 84	$ 405,300
8"	6,946	LF	$ 112	$ 777,952
10"	0	LF	$ 140	$ -
12"	138,481	LF	$ 168	$ 23,264,808
14"	0	LF	$ 196	$ -
16"	131,416	LF	$ 224	$ 29,437,184
18"	0	LF	$ 252	$ -
20"	4,243	LF	$ 280	$ 1,188,040
24"	33,461	LF	$ 336	$ 11,242,896
30"	0	LF	$ 420	$ -
36"	489	LF	$ 504	$ 246,456
Pressure Reducing Valves				
3 to < 6 mgd	3	each	$ 388,641	$ 1,165,923
6 to < 15 mgd	1	each	$ 154,403	$ 154,403
Reservoirs	0	MG	$ 1,515,156	$ -
Booster Pump Stations				
0 to < 7 mgd	8.4	mgd	$ 361,571	$ 3,037,198
7 to < 13 mgd	12.7	mgd	$ 229,316	$ 2,912,311
13 to < 17 mgd	0	mgd	$ 190,552	$ -
17 to < 25 mgd	0	mgd	$ 163,770	$ -
25 to < 35 mgd	0	mgd	$ 128,054	$ -
Production Wells	13	each	$ 2,192,091	$ 28,497,182
Wellhead Rehabilitation	1	each	$ 1,000,000	$ 1,000,000
Water Treatment Plant	0	mgd	$ 3,082,576	$ -
Arsenic Treatment	5	mgd	$ 1,301,014	$ 6,752,261
TDS Treatment	0	mgd	$ 4,411,460	$ -
TOTAL CAPITAL COST				$ 110,081,914
O&M COSTS				
Pipelines	60.6	miles	$ 3,738	$ 226,459
Reservoirs	0	each	$ 7,476.38	$ -
Booster Pump Stations				
Power	8,179,347	kwh	$ 0.08	$ 654,348
Maintenance	1	3% of Capital	$ 178,485	$ 178,485
Production Wells	9,636,000	1,000 gallons	$ 0.21	$ 2,046,786
Wellhead Arsenic Treatment	2,574,389	1,000 gallons	$ 0.55	$ 1,421,750
Wellhead TDS Treatment	0	1,000 gallons	$ 0.85	$ -
Water Treatment Plant	0	1,000 gallons	$ 0.71	$ -
Recharge (Avondale Facility)	13,390,225	1,000 gallons	$ 0.06	$ 782,113
Regional Recharge O&M (CAWCD)	6,298	AF	$ 23	$ 144,854
Regional Recharge O&M (NAUSP)	7,410	AF	$ 24	$ 177,840
Wheeling Fees	5,416	AF	$ 23	$ 124,568
TOTAL O&M COST				$ 5,757,203
PRESENT WORTH OF O&M[2]				$ 66,034,665
TOTAL PRESENT WORTH[2]				$ 176,116,579

NOTES:

[1] November 2009 Costs (ENR CCI = 8,592).

[2] 20 Years, 6 Percent Interest.

Alternative 2: Continue to Build Wells Around Avondale Recharge Facility
(25 Percent Groundwater Treatment By Volume)

ITEM	QUANTITY	UNITS	UNIT COST	COST[1]
CAPITAL COSTS				
Pipelines				
6"	4,825	LF	$ 84	$ 405,300
8"	6,946	LF	$ 112	$ 777,952
10"	0	LF	$ 140	$ -
12"	138,481	LF	$ 168	$ 23,264,808
14"	0	LF	$ 196	$ -
16"	131,416	LF	$ 224	$ 29,437,184
18"	0	LF	$ 252	$ -
20"	4,243	LF	$ 280	$ 1,188,040
24"	33,461	LF	$ 336	$ 11,242,896
30"	0	LF	$ 420	$ -
36"	489	LF	$ 504	$ 246,456
Pressure Reducing Valves				
3 to < 6 mgd	3	each	$ 388,641	$ 1,165,923
6 to < 15 mgd	1	each	$ 154,403	$ 154,403
Reservoirs	0	MG	$ 1,515,156	$ -
Booster Pump Stations				
0 to < 7 mgd	8.4	mgd	$ 361,571	$ 3,037,198
7 to < 13 mgd	12.7	mgd	$ 229,316	$ 2,912,311
13 to < 17 mgd	0	mgd	$ 190,552	$ -
17 to < 25 mgd	0	mgd	$ 163,770	$ -
25 to < 35 mgd	0	mgd	$ 128,054	$ -
Production Wells	13	each	$ 2,192,091	$ 28,497,182
Wellhead Rehabilitation	1	each	$ 1,000,000	$ 1,000,000
Water Treatment Plant	0	mgd	$ 3,082,576	$ -
Arsenic Treatment	5	mgd	$ 1,301,014	$ 6,752,261
TDS Treatment	0	mgd	$ 4,411,460	$ -
TOTAL CAPITAL COST				$ 110,081,914
O&M COSTS				
Pipelines	60.6	miles	$ 3,738	$ 226,459
Reservoirs	0	each	$ 7,476.38	$ -
Booster Pump Stations				
Power	8,179,347	kwh	$ 0.08	$ 654,348
Maintenance	1	3% of Capital	$ 178,485	$ 178,485
Production Wells	9,636,000	1,000 gallons	$ 0.21	$ 2,046,786
Wellhead Arsenic Treatment	2,574,389	1,000 gallons	$ 0.55	$ 1,421,750
Wellhead TDS Treatment	0	1,000 gallons	$ 0.85	$ -
Water Treatment Plant	0	1,000 gallons	$ 0.71	$ -
Recharge (Avondale Facility)	13,390,225	1,000 gallons	$ 0.06	$ 782,113
Regional Recharge O&M (CAWCD)	6,298	AF	$ 23	$ 144,854
Regional Recharge O&M (NAUSP)	7,410	AF	$ 24	$ 177,840
Wheeling Fees	5,416	AF	$ 23	$ 124,568
TOTAL O&M COST				$ 5,757,203
PRESENT WORTH OF O&M[2]				$ 66,034,665
TOTAL PRESENT WORTH[2]				$ 176,116,579

NOTES:

[1] November 2009 Costs (ENR CCI = 8,592).

[2] 20 Years, 6 Percent Interest.

Alternative 3: Continue to Build Wells Throughut Service Area
(25 Percent Groundwater Treatment By Volume)

ITEM	QUANTITY	UNITS	UNIT COST	COST[1]
CAPITAL COSTS				
Pipelines				
6"	4,825	LF	$ 84	$ 405,300
8"	7,447	LF	$ 112	$ 834,065
10"	0	LF	$ 140	$ -
12"	132,215	LF	$ 168	$ 22,212,120
14"		LF	$ 196	$ -
16"	131,513	LF	$ 224	$ 29,458,912
18"	0	LF	$ 252	$ -
20"	22,678	LF	$ 280	$ 6,349,840
24"	21,542	LF	$ 336	$ 7,238,112
30"	0	LF	$ 420	$ -
36"	489	LF	$ 504	$ 246,456
Pressure Reducing Valves				
3 to < 6 mgd	0	each	$ 388,641	$ -
6 to < 15 mgd	0	each	$ 154,403	$ -
Reservoirs	0	MG	$ 1,515,156	$ -
Booster Pump Stations				
0 to < 7 mgd	11.86	mgd	$ 361,571	$ 4,288,235
7 to < 13 mgd	9.22	mgd	$ 229,316	$ 2,114,292
13 to < 17 mgd	0	mgd	$ 190,552	$ -
17 to < 25 mgd	0	mgd	$ 163,770	$ -
25 to < 35 mgd	0	mgd	$ 128,054	$ -
Production Wells	13	each	$ 2,192,091	$ 28,497,182
Wellhead Rehabilitation	1	each	$ 1,000,000	$ 1,000,000
Water Treatment Plant	0	mgd	$ 3,082,576	$ -
Arsenic Treatment	3	mgd	$ 1,301,014	$ 4,501,507
TDS Treatment	5	mgd	$ 4,411,460	$ 21,322,059
TOTAL CAPITAL COST				$ 128,468,080
O&M COSTS				
Pipelines	60.7	miles	$ 3,738	$ 227,059
Reservoirs	0	each	$ 7,476.38	$ -
Booster Pump Stations				
Power	7,767,691	kwh	$ 0.08	$ 621,415
Maintenance	1	3% of Capital	$ 192,076	$ 192,076
Production Wells	9,636,000	1,000 gallons	$ 0.21	$ 2,046,786
Wellhead Arsenic Treatment	2,320,524	1,000 gallons	$ 0.55	$ 1,281,549
Wellhead TDS Treatment	761,594	1,000 gallons	$ 0.85	$ 647,062
Water Treatment Plant	0	1,000 gallons	$ 0.71	$ -
Recharge (Avondale Facility)	13,390,225	1,000 gallons	$ 0.06	$ 782,113
Regional Recharge O&M (CAWCD)	6,298	AF	$ 23	$ 144,854
Regional Recharge O&M (NAUSP)	7,410	AF	$ 24	$ 177,840
Wheeling Fees	5,416	AF	$ 23	$ 124,568
TOTAL O&M COST				$ 6,245,322
PRESENT WORTH OF O&M[2]				$ 71,633,352
TOTAL PRESENT WORTH[2]				$ 200,101,431

NOTES:

[1] November 2009 Costs (ENR CCI = 8,592).

[2] 20 Years, 6 Percent Interest.

Alternative 4: Build a Surface WTP Near Avondale Recharge Facility
(25 Percent Groundwater Treatment By Volume)

ITEM	QUANTITY	UNITS	UNIT COST	COST[1]
CAPITAL COSTS				
Pipelines				
6"	4,825	LF	$ 84	$ 405,287
8"	7,447	LF	$ 112	$ 834,065
10"	0	LF	$ 140	$ -
12"	119,603	LF	$ 168	$ 20,093,260
14"	0	LF	$ 196	$ -
16"	105,754	LF	$ 224	$ 23,688,912
18"	0	LF	$ 252	$ -
20"	17,608	LF	$ 280	$ 4,930,111
24"	35,042	LF	$ 336	$ 11,774,226
30"	1,600	LF	$ 420	$ 672,000
36"	490	LF	$ 504	$ 247,081
Pressure Reducing Valves				
3 to < 6 mgd	0	each	$ 388,641	$ -
6 to < 15 mgd	0	each	$ 154,403	$ -
Reservoirs	0	MG	$ 1,515,156	$ -
Booster Pump Stations				
0 to < 7 mgd	8.67	mgd	$ 361,571	$ 3,134,823
7 to < 13 mgd	9.82	mgd	$ 229,316	$ 2,251,882
13 to < 17 mgd	0	mgd	$ 190,552	$ -
17 to < 25 mgd	0	mgd	$ 163,770	$ -
25 to < 35 mgd	25	mgd	$ 128,054	SEE WTP
Production Wells	8	each	$ 2,192,091	$ 17,536,727
Wellhead Rehabilitation	1	each	$ 1,000,000	$ 1,000,000
Water Treatment Plant	15	mgd	$ 3,082,576	$ 46,238,641
Arsenic Treatment	3	mgd	$ 1,301,014	$ 4,501,507
TDS Treatment	0	mgd	$ 4,411,460	$ -
TOTAL CAPITAL COST				$ 137,308,521
O&M COSTS				
Pipelines	55.4	miles	$ 3,738	$ 206,994
Reservoirs	0	each	$ 7,476.38	$ -
Booster Pump Stations				
Power	9,000,434	kwh	$ 0.08	$ 720,035
Maintenance	1	3% of Capital	$ 161,601	$ 161,601
Production Wells	4,161,000	1,000 gallons	$ 0.21	$ 883,840
Wellhead Arsenic Treatment	424,685	1,000 gallons	$ 0.55	$ 234,539
Wellhead TDS Treatment	0	1,000 gallons	$ 0.85	$ -
Water Treatment Plant	5,475,000	1,000 gallons	$ 0.71	$ 3,876,367
Recharge (Avondale Facility)	8,496,544	1,000 gallons	$ 0.06	$ 496,277
Regional Recharge O&M (CAWCD)	0	AF	$ 23	$ -
Regional Recharge O&M (NAUSP)	2,387	AF	$ 24	$ 57,288
Wheeling Fees	5,416	AF	$ 23	$ 124,568
TOTAL O&M COST				$ 6,761,509
PRESENT WORTH OF O&M[2]				$ 77,553,971
TOTAL PRESENT WORTH[2]				$ 214,862,493

NOTES:

[1] November 2009 Costs (ENR CCI = 8,592).

[2] 20 Years, 6 Percent Interest.

Alternative 5: Build a Surface WTP Near 107th Ave. and Roosevelt Rd.
(25 Percent Groundwater Treatment By Volume)

ITEM	QUANTITY	UNITS	UNIT COST	COST[1]
CAPITAL COSTS				
Pipelines				
6"	4,825	LF	$ 84	$ 405,287
8"	7,447	LF	$ 112	$ 834,065
10"	0	LF	$ 140	$ -
12"	119,603	LF	$ 168	$ 20,093,260
14"	0	LF	$ 196	$ -
16"	105,754	LF	$ 224	$ 23,688,912
18"	0	LF	$ 252	$ -
20"	17,608	LF	$ 280	$ 4,930,111
24"	26,842	LF	$ 336	$ 9,019,026
30"	8,100	LF	$ 420	$ 3,402,000
36"	490	LF	$ 504	$ 247,081
Pressure Reducing Valves				
3 to < 6 mgd	0	each	$ 388,641	$ -
6 to < 15 mgd	0	each	$ 154,403	$ -
Reservoirs	0	MG	$ 1,515,156	$ -
Booster Pump Stations				
0 to < 7 mgd	8.67	mgd	$ 361,571	$ 3,134,823
7 to < 13 mgd	9.82	mgd	$ 229,316	$ 2,251,882
13 to < 17 mgd	0	mgd	$ 190,552	$ -
17 to < 25 mgd	0	mgd	$ 163,770	$ -
25 to < 35 mgd	25	mgd	$ 128,054	SEE WTP
Production Wells	8	each	$ 2,192,091	$ 17,536,727
Wellhead Rehabilitation	1	each	$ 1,000,000	$ 1,000,000
Water Treatment Plant	15	mgd	$ 3,082,576	$ 46,238,641
Arsenic Treatment	3	mgd	$ 1,301,014	$ 4,501,507
TDS Treatment	0	mgd	$ 4,411,460	$ -
TOTAL CAPITAL COST				$ 137,283,321
O&M COSTS				
Pipelines	55.1	miles	$ 3,738	$ 205,791
Reservoirs	0	each	$ 7,476.38	$ -
Booster Pump Stations				
Power	9,000,434	kwh	$ 0.08	$ 720,035
Maintenance	1	3% of Capital	$ 161,601	$ 161,601
Production Wells	4,161,000	1,000 gallons	$ 0.21	$ 883,840
Wellhead Arsenic Treatment	424,685	1,000 gallons	$ 0.55	$ 234,539
Wellhead TDS Treatment	0	1,000 gallons	$ 0.85	$ -
Water Treatment Plant	5,475,000	1,000 gallons	$ 0.71	$ 3,876,367
Recharge (Avondale Facility)	8,496,544	1,000 gallons	$ 0.06	$ 496,277
Regional Recharge O&M (CAWCD)	0	AF	$ 23	$ -
Regional Recharge O&M (NAUSP)	2,387	AF	$ 24	$ 57,288
Wheeling Fees	5,416	AF	$ 23	$ 124,568
TOTAL O&M COST				$ 6,760,305
PRESENT WORTH OF O&M[2]				$ 77,540,166
TOTAL PRESENT WORTH[2]				$ 214,823,488

NOTES:

[1] November 2009 Costs (ENR CCI = 8,592).

[2] 20 Years, 6 Percent Interest.

Alternative 1: Continue to Build Wells East of Dysart Road
(75 Percent Groundwater Treatment By Volume)

ITEM	QUANTITY	UNITS	UNIT COST	COST[1]
CAPITAL COSTS				
Pipelines				
6"	4,825	LF	$ 84	$ 405,300
8"	6,946	LF	$ 112	$ 777,952
10"	0	LF	$ 140	$ -
12"	138,481	LF	$ 168	$ 23,264,808
14"	0	LF	$ 196	$ -
16"	131,416	LF	$ 224	$ 29,437,184
18"	0	LF	$ 252	$ -
20"	4,243	LF	$ 280	$ 1,188,040
24"	33,461	LF	$ 336	$ 11,242,896
30"	0	LF	$ 420	$ -
36"	489	LF	$ 504	$ 246,456
Pressure Reducing Valves				
3 to < 6 mgd	3	each	$ 388,641	$ 1,165,923
6 to < 15 mgd	1	each	$ 154,403	$ 154,403
Reservoirs	0	MG	$ 1,515,156	$ -
Booster Pump Stations				
0 to < 7 mgd	8.4	mgd	$ 361,571	$ 3,037,198
7 to < 13 mgd	12.7	mgd	$ 229,316	$ 2,912,311
13 to < 17 mgd	0	mgd	$ 190,552	$ -
17 to < 25 mgd	0	mgd	$ 163,770	$ -
25 to < 35 mgd	0	mgd	$ 128,054	$ -
Production Wells	13	each	$ 2,192,091	$ 28,497,182
Wellhead Rehabilitation	1	each	$ 1,000,000	$ 1,000,000
Water Treatment Plant	0	mgd	$ 3,082,576	$ -
Arsenic Treatment	16	mgd	$ 1,301,014	$ 20,256,782
TDS Treatment	0	mgd	$ 4,411,460	$ -
TOTAL CAPITAL COST				$ 123,586,435
O&M COSTS				
Pipelines	60.6	miles	$ 3,738	$ 226,459
Reservoirs	0	each	$ 7,476.38	$ -
Booster Pump Stations				
Power	8,179,347	kwh	$ 0.08	$ 654,348
Maintenance	1	3% of Capital	$ 178,485	$ 178,485
Production Wells	9,636,000	1,000 gallons	$ 0.21	$ 2,046,786
Wellhead Arsenic Treatment	4,097,578	1,000 gallons	$ 0.55	$ 2,262,957
Wellhead TDS Treatment	0	1,000 gallons	$ 0.85	$ -
Water Treatment Plant	0	1,000 gallons	$ 0.71	$ -
Recharge (Avondale Facility)	13,390,225	1,000 gallons	$ 0.06	$ 782,113
Regional Recharge O&M (CAWCD)	6,298	AF	$ 23	$ 144,854
Regional Recharge O&M (NAUSP)	7,410	AF	$ 24	$ 177,840
Wheeling Fees	5,416	AF	$ 23	$ 124,568
TOTAL O&M COST				$ 6,598,410
PRESENT WORTH OF O&M[2]				$ 75,683,242
TOTAL PRESENT WORTH[2]				$ 199,269,677

NOTES:

[1] November 2009 Costs (ENR CCI = 8,592).

[2] 20 Years, 6 Percent Interest.

Alternative 2: Continue to Build Wells Around Avondale Recharge Facility
(75 Percent Groundwater Treatment By Volume)

ITEM	QUANTITY	UNITS	UNIT COST	COST[1]
CAPITAL COSTS				
Pipelines				
6"	4,825	LF	$ 84	$ 405,300
8"	6,946	LF	$ 112	$ 777,952
10"	0	LF	$ 140	$ -
12"	138,481	LF	$ 168	$ 23,264,808
14"	0	LF	$ 196	$ -
16"	131,416	LF	$ 224	$ 29,437,184
18"	0	LF	$ 252	$ -
20"	4,243	LF	$ 280	$ 1,188,040
24"	33,461	LF	$ 336	$ 11,242,896
30"	0	LF	$ 420	$ -
36"	489	LF	$ 504	$ 246,456
Pressure Reducing Valves				
3 to < 6 mgd	3	each	$ 388,641	$ 1,165,923
6 to < 15 mgd	1	each	$ 154,403	$ 154,403
Reservoirs	0	MG	$ 1,515,156	$ -
Booster Pump Stations				
0 to < 7 mgd	8.4	mgd	$ 361,571	$ 3,037,198
7 to < 13 mgd	12.7	mgd	$ 229,316	$ 2,912,311
13 to < 17 mgd	0	mgd	$ 190,552	$ -
17 to < 25 mgd	0	mgd	$ 163,770	$ -
25 to < 35 mgd	0	mgd	$ 128,054	$ -
Production Wells	13	each	$ 2,192,091	$ 28,497,182
Wellhead Rehabilitation	1	each	$ 1,000,000	$ 1,000,000
Water Treatment Plant	0	mgd	$ 3,082,576	$ -
Arsenic Treatment	16	mgd	$ 1,301,014	$ 20,256,782
TDS Treatment	0	mgd	$ 4,411,460	$ -
TOTAL CAPITAL COST				$ 123,586,435
O&M COSTS				
Pipelines	60.6	miles	$ 3,738	$ 226,459
Reservoirs	0	each	$ 7,476.38	$ -
Booster Pump Stations				
Power	8,179,347	kwh	$ 0.08	$ 654,348
Maintenance	1	3% of Capital	$ 178,485	$ 178,485
Production Wells	9,636,000	1,000 gallons	$ 0.21	$ 2,046,786
Wellhead Arsenic Treatment	4,097,578	1,000 gallons	$ 0.55	$ 2,262,957
Wellhead TDS Treatment	0	1,000 gallons	$ 0.85	$ -
Water Treatment Plant	0	1,000 gallons	$ 0.71	$ -
Recharge (Avondale Facility)	13,390,225	1,000 gallons	$ 0.06	$ 782,113
Regional Recharge O&M (CAWCD)	6,298	AF	$ 23	$ 144,854
Regional Recharge O&M (NAUSP)	7,410	AF	$ 24	$ 177,840
Wheeling Fees	5,416	AF	$ 23	$ 124,568
TOTAL O&M COST				$ 6,598,410
PRESENT WORTH OF O&M[2]				$ 75,683,242
TOTAL PRESENT WORTH[2]				$ 199,269,677

NOTES:

[1] November 2009 Costs (ENR CCI = 8,592).

[2] 20 Years, 6 Percent Interest.

Alternative 3: Continue to Build Wells Throughut Service Area
(75 Percent Groundwater Treatment By Volume)

ITEM	QUANTITY	UNITS	UNIT COST	COST[1]
CAPITAL COSTS				
Pipelines				
6"	4,825	LF	$ 84	$ 405,300
8"	7,447	LF	$ 112	$ 834,065
10"	0	LF	$ 140	$ -
12"	132,215	LF	$ 168	$ 22,212,120
14"		LF	$ 196	$ -
16"	131,513	LF	$ 224	$ 29,458,912
18"	0	LF	$ 252	$ -
20"	22,678	LF	$ 280	$ 6,349,840
24"	21,542	LF	$ 336	$ 7,238,112
30"	0	LF	$ 420	$ -
36"	489	LF	$ 504	$ 246,456
Pressure Reducing Valves				
3 to < 6 mgd	0	each	$ 388,641	$ -
6 to < 15 mgd	0	each	$ 154,403	$ -
Reservoirs	0	MG	$ 1,515,156	$ -
Booster Pump Stations				
0 to < 7 mgd	11.86	mgd	$ 361,571	$ 4,288,235
7 to < 13 mgd	9.22	mgd	$ 229,316	$ 2,114,292
13 to < 17 mgd	0	mgd	$ 190,552	$ -
17 to < 25 mgd	0	mgd	$ 163,770	$ -
25 to < 35 mgd	0	mgd	$ 128,054	$ -
Production Wells	13	each	$ 2,192,091	$ 28,497,182
Wellhead Rehabilitation	1	each	$ 1,000,000	$ 1,000,000
Water Treatment Plant	0	mgd	$ 3,082,576	$ -
Arsenic Treatment	10	mgd	$ 1,301,014	$ 13,504,521
TDS Treatment	5	mgd	$ 4,411,460	$ 21,322,059
TOTAL CAPITAL COST				$ 137,471,094
O&M COSTS				
Pipelines	60.7	miles	$ 3,738	$ 227,059
Reservoirs	0	each	$ 7,476.38	$ -
Booster Pump Stations				
Power	7,767,691	kwh	$ 0.08	$ 621,415
Maintenance	1	3% of Capital	$ 192,076	$ 192,076
Production Wells	9,636,000	1,000 gallons	$ 0.21	$ 2,046,786
Wellhead Arsenic Treatment	3,335,983	1,000 gallons	$ 0.55	$ 1,842,353
Wellhead TDS Treatment	761,594	1,000 gallons	$ 0.85	$ 647,062
Water Treatment Plant	0	1,000 gallons	$ 0.71	$ -
Recharge (Avondale Facility)	13,390,225	1,000 gallons	$ 0.06	$ 782,113
Regional Recharge O&M (CAWCD)	6,298	AF	$ 23	$ 144,854
Regional Recharge O&M (NAUSP)	7,410	AF	$ 24	$ 177,840
Wheeling Fees	5,416	AF	$ 23	$ 124,568
TOTAL O&M COST				$ 6,806,127
PRESENT WORTH OF O&M[2]				$ 78,065,736
TOTAL PRESENT WORTH[2]				$ 215,536,830

NOTES:

[1] November 2009 Costs (ENR CCI = 8,592).

[2] 20 Years, 6 Percent Interest.

Alternative 4: Build a Surface WTP Near Avondale Recharge Facility
(75 Percent Groundwater Treatment By Volume)

ITEM	QUANTITY	UNITS	UNIT COST	COST[1]
CAPITAL COSTS				
Pipelines				
6"	4,825	LF	$ 84	$ 405,287
8"	7,447	LF	$ 112	$ 834,065
10"	0	LF	$ 140	$ -
12"	119,603	LF	$ 168	$ 20,093,260
14"	0	LF	$ 196	$ -
16"	105,754	LF	$ 224	$ 23,688,912
18"	0	LF	$ 252	$ -
20"	17,608	LF	$ 280	$ 4,930,111
24"	35,042	LF	$ 336	$ 11,774,226
30"	1,600	LF	$ 420	$ 672,000
36"	490	LF	$ 504	$ 247,081
Pressure Reducing Valves				
3 to < 6 mgd	0	each	$ 388,641	$ -
6 to < 15 mgd	0	each	$ 154,403	$ -
Reservoirs	0	MG	$ 1,515,156	$ -
Booster Pump Stations				
0 to < 7 mgd	8.67	mgd	$ 361,571	$ 3,134,823
7 to < 13 mgd	9.82	mgd	$ 229,316	$ 2,251,882
13 to < 17 mgd	0	mgd	$ 190,552	$ -
17 to < 25 mgd	0	mgd	$ 163,770	$ -
25 to < 35 mgd	25	mgd	$ 128,054	SEE WTP
Production Wells	8	each	$ 2,192,091	$ 17,536,727
Wellhead Rehabilitation	1	each	$ 1,000,000	$ 1,000,000
Water Treatment Plant	15	mgd	$ 3,082,576	$ 46,238,641
Arsenic Treatment	9	mgd	$ 1,301,014	$ 11,253,768
TDS Treatment	0	mgd	$ 4,411,460	$ -
TOTAL CAPITAL COST				$ 144,060,782
O&M COSTS				
Pipelines	55.4	miles	$ 3,738	$ 206,994
Reservoirs	0	each	$ 7,476.38	$ -
Booster Pump Stations				
Power	9,000,434	kwh	$ 0.08	$ 720,035
Maintenance	1	3% of Capital	$ 161,601	$ 161,601
Production Wells	4,161,000	1,000 gallons	$ 0.21	$ 883,840
Wellhead Arsenic Treatment	743,198	1,000 gallons	$ 0.55	$ 410,444
Wellhead TDS Treatment	0	1,000 gallons	$ 0.85	$ -
Water Treatment Plant	5,475,000	1,000 gallons	$ 0.71	$ 3,876,367
Recharge (Avondale Facility)	8,496,544	1,000 gallons	$ 0.06	$ 496,277
Regional Recharge O&M (CAWCD)	0	AF	$ 23	$ -
Regional Recharge O&M (NAUSP)	2,387	AF	$ 24	$ 57,288
Wheeling Fees	5,416	AF	$ 23	$ 124,568
TOTAL O&M COST				$ 6,937,413
PRESENT WORTH OF O&M[2]				$ 79,571,582
TOTAL PRESENT WORTH[2]				$ 223,632,365

NOTES:

[1] November 2009 Costs (ENR CCI = 8,592).

[2] 20 Years, 6 Percent Interest.

Alternative 5: Build a Surface WTP Near 107th Ave. and Roosevelt Rd.
(75 Percent Groundwater Treatment By Volume)

ITEM	QUANTITY	UNITS	UNIT COST	COST[1]
CAPITAL COSTS				
Pipelines				
6"	4,825	LF	$ 84	$ 405,287
8"	7,447	LF	$ 112	$ 834,065
10"	0	LF	$ 140	$ -
12"	119,603	LF	$ 168	$ 20,093,260
14"	0	LF	$ 196	$ -
16"	105,754	LF	$ 224	$ 23,688,912
18"	0	LF	$ 252	$ -
20"	17,608	LF	$ 280	$ 4,930,111
24"	26,842	LF	$ 336	$ 9,019,026
30"	8,100	LF	$ 420	$ 3,402,000
36"	490	LF	$ 504	$ 247,081
Pressure Reducing Valves				
3 to < 6 mgd	0	each	$ 388,641	$ -
6 to < 15 mgd	0	each	$ 154,403	$ -
Reservoirs	0	MG	$ 1,515,156	$ -
Booster Pump Stations				
0 to < 7 mgd	8.67	mgd	$ 361,571	$ 3,134,823
7 to < 13 mgd	9.82	mgd	$ 229,316	$ 2,251,882
13 to < 17 mgd	0	mgd	$ 190,552	$ -
17 to < 25 mgd	0	mgd	$ 163,770	$ -
25 to < 35 mgd	25	mgd	$ 128,054	SEE WTP
Production Wells	8	each	$ 2,192,091	$ 17,536,727
Wellhead Rehabilitation	1	each	$ 1,000,000	$ 1,000,000
Water Treatment Plant	15	mgd	$ 3,082,576	$ 46,238,641
Arsenic Treatment	9	mgd	$ 1,301,014	$ 11,253,768
TDS Treatment	0	mgd	$ 4,411,460	$ -
TOTAL CAPITAL COST				$ 144,035,582
O&M COSTS				
Pipelines	55.1	miles	$ 3,738	$ 205,791
Reservoirs	0	each	$ 7,476.38	$ -
Booster Pump Stations				
Power	9,000,434	kwh	$ 0.08	$ 720,035
Maintenance	1	3% of Capital	$ 161,601	$ 161,601
Production Wells	4,161,000	1,000 gallons	$ 0.21	$ 883,840
Wellhead Arsenic Treatment	743,198	1,000 gallons	$ 0.55	$ 410,444
Wellhead TDS Treatment	0	1,000 gallons	$ 0.85	$ -
Water Treatment Plant	5,475,000	1,000 gallons	$ 0.71	$ 3,876,367
Recharge (Avondale Facility)	8,496,544	1,000 gallons	$ 0.06	$ 496,277
Regional Recharge O&M (CAWCD)	0	AF	$ 23	$ -
Regional Recharge O&M (NAUSP)	2,387	AF	$ 24	$ 57,288
Wheeling Fees	5,416	AF	$ 23	$ 124,568
TOTAL O&M COST				$ 6,936,210
PRESENT WORTH OF O&M[2]				$ 79,557,777
TOTAL PRESENT WORTH[2]				$ 223,593,359

NOTES:

[1] November 2009 Costs (ENR CCI = 8,592).

[2] 20 Years, 6 Percent Interest.

F. Groundwater Flow Modeling

THIS PAGE INTENTIONALLY LEFT BLANK

City of Avondale

399 East Lower Buckeye Road Suite 100. Avondale, AZ 85323

Water Resource Master Plan

Groundwater Flow Modeling

May 2010

Report Prepared By:

Malcolm Pirnie, Inc.

4646 East Van Buren Street
Suite 400
Phoenix, AZ 85008

0864-025

Contents

1. Introduction 1-1

1.1. Background ... 1-1

2. Model Development 2-1

2.1. Description of Previous Groundwater Flow Models ... 2-1
2.1.1. Model Descritization ... 2-1
2.1.2. Model Boundaries ... 2-2
2.1.3. Hydraulic Properties ... 2-3
2.1.3.1. Hydraulic Conductivity ... 2-3
2.1.3.2. Storage Coefficients ... 2-3
2.1.4. Streams ... 2-4
2.1.5. Recharge ... 2-4
2.1.6. Evapotranspiration ... 2-6
2.1.7. Pumping ... 2-6

2.2. Model Refinement ... 2-6
2.2.1. Physical Description of the Avondale Water System ... 2-7
2.2.2. Model Grid ... 2-9
2.2.3. Model Boundaries ... 2-10
2.2.4. Model Layers ... 2-11
2.2.5. Hydraulic Properties ... 2-12
2.2.6. Streams ... 2-13
2.2.6.1. Segments ... 2-13
2.2.6.2. Stream flows ... 2-14
2.2.6.3. Stream Stage ... 2-14
2.2.6.4. Conductance ... 2-15
2.2.7. Recharge and Evapotranspiration ... 2-15
2.2.8. Wells ... 2-16
2.2.9. Calibration/Verification ... 2-16
2.2.9.1. Flow Budgets ... 2-16
2.2.9.2. Groundwater Elevations ... 2-18
2.2.9.3. Hydrographs ... 2-21
2.2.9.4. Flow Patterns ... 2-21
2.2.9.5. Summary ... 2-22

3. Alternative Simulations 3-1

3.1. General ... 3-1

3.2. Drivers ... 3-1

3.3. Potential Water Supply Alternatives ... 3-3
3.3.1. Alternative 1 ... 3-3
3.3.2. Alternative 2 ... 3-4
3.3.3. Alternative 3 ... 3-4
3.3.4. Alternatives 4 and 5 ... 3-4

3.4. Future Regional Stress Conditions ... 3-5
3.4.1. Historical Conditions ... 3-6
3.4.2. Assumed Future Stress Conditions ... 3-6

3.5. Model Response 3-8
3.6. Simulation Methods 3-8
3.7. Model Corrections 3-11
3.8. Simulation Results 3-13
3.8.1. Drawdowns 3-13
3.8.2. Potentiometric Surface 3-14
3.8.3. Mounding 3-15
3.8.4. Contaminant Plumes 3-16
3.8.5. Well Operations 3-17
3.9. Summary of Results 3-19

4. References 4-1

A: Digital Groundwater Flow Modeling Files 4-1

B: Model Water Budgets 4-1

C: Model Residual Summary 4-1

D: Assumed Annual Pumping for Water Supply Alternatives 4-1

List of Tables

Table 2-1: Summary of Simulated Hydraulic Properties 2-3
Table 2-2: Summary of Avondale Groundwater Wells 2-8
Table 2-3: Contact Elevations for Recent Avondale Groundwater Wells 2-12
Table 2-4: Hydraulic Properties for Recent Avondale Supply Wells 2-13
Table 2-5: Unweighted Residual Error Summaries for the ADWR Model 2-19
Table 2-6: Unweighted Residual Error Summaries for the Refined ADWR Model 2-20
Table 3-1: Pump, Perforated Interval, and Critical Elevation Assumptions 3-10
Table 3-2: Predicted Mounding Effect 3-15
Table 3-3: Predicted Drawdowns at Contaminant Plumes 3-16
Table 3-4: Predicted Groundwater Elevations at Avondale Wells 3-18

Figures

1. ADWR Model Boundaries
2. ADWR Model Grid
3. Geologic Cross Section Locations
4. Generalized Geologic Cross Sections
5. Avondale Water System
6. Refined Model Boundaries
7. Refined Model Grid

8. Hydraulic Conductivity – Layer One
9. Hydraulic Conductivity – Layer Two
10. Hydraulic Conductivity – Layer Three
11. Specific Yield – Layer One
12. Specific Yield – Layer Two
13. Specific Yield – Layer Three
14. Streams
15. 2006 Total Recharge
16. Evapotranspiration Rate
17. Model Error – Winter 1991/1992 Water Level Sweep
18. Model Error – Winter 1997/1998 Water Level Sweep
19. Model Error – Winter 2002/2003 Water Level Sweep
20. Model Error – Avondale Study Area – Winter 1991/1992 Water Level Sweep
21. Model Error – Avondale Study Area – Winter 1997/1998 Water Level Sweep
22. Model Error – Avondale Study Area – Winter 2002/2003 Water Level Sweep
23. Model Error – Avondale Study Area – ADWR Index Well Hydrograph Locations
24. Model Error – Avondale Study Area – Index Wells B-02-01 26ACA and B-02-01 36BBA3 Hydrographs
25. Model Error – Avondale Study Area – Index Wells B-02-01 34CAA2 and A-02-01 31DAA Hydrographs
26. Model Error – Avondale Study Area – Index Wells A-01-01 6CBB1 and B-01-01 10AA2 Hydrographs
27. Model Error – Avondale Study Area – Index Wells B-01-01 12 BAA2 and A-01-01 7CCD Hydrographs
28. Model Error – Avondale Study Area – Index Wells B-01-01 27DAB2 and B-01-01 25BAA Hydrographs
29. Model Error – Avondale Study Area – Index Wells B-02-01 26ACE Hydrograph
30. Winter 1997/1998 Simulated vs. Observed Flow Patterns – Avondale Study Area
31. Water Quality Favorability Map
32. Alternative 1 – Well Layout Map
33. Alternative 2 – Well Layout Map
34. Alternative 3 – Well Layout Map
35. Alternatives 4 and 5 – Well Layout Map
36. Simulated Regional Stress Conditions 1983-2006
37. Base Case Future Simulated Water Level Trends – Index Wells B-02-01 26ACA and A-02-01 31DAA Hydrographs
38. Base Case Future Simulated Water Level Trends – Index Wells B-01-01 10AAA2 and B-01-01 25BAA Hydrographs
39. Alternative 1 – 2050 Drawdown Map
40. Alternative 2 – 2050 Drawdown Map
41. Alternative 3 – 2050 Drawdown Map
42. Alternatives 4 and 5 – 2050 Drawdown Map
43. Alternative 1 – 2050 Simulated Potentiometric Surface Map
44. Alternative 2 – 2050 Simulated Potentiometric Surface Map
45. Alternative 3 – 2050 Simulated Potentiometric Surface Map
46. Alternatives 4 and 5 – 2050 Simulated Potentiometric Surface Map

Appendices

A. Digital Groundwater Flow Modeling Files
B. Model Water Budgets

C. Model Residual Summary
D. Assumed Annual Pumping Rates (Alternatives 1 through 5)

1. Introduction

1.1. Background

The City of Avondale (City) is updating its Water Resource Master Plan (WRMP) to reflect changes in the City's general plan and land use plan and in growth projections within the City's planning area. The planning period for the WRMP update extends to the year 2050. As part of the WRMP study, a groundwater flow model was developed to support the evaluation of the potential water supply alternatives being considered to address future growth in demands within the planning area. The evaluation included simulation of the following general water supply alternatives:

- The effects of increased recharge of reclaimed water at the City's recharge facility
- The potential for recovery wells near the City's recharge facility
- Operational issues associated with extended recharge of reclaimed water
- Operational considerations necessary to balance recharge and pumping of reclaimed water
- Potential impacts of water supply development on existing contaminant plumes

The groundwater flow model was based on the existing Arizona Department of Water Resources (ADWR) model for the Salt River Valley (SRV). The ADWR model was modified to focus on simulating the flow and occurrence of groundwater within the Avondale water service area and surrounding vicinity. The following sections describe the conversion of the ADWR model to a smaller, more localized model for the Avondale area, calibration/verification of the refined model, and general use of the model to evaluate the potential water supply alternatives. Digital electronic files of the groundwater flow model are provided in Appendix A.

2. Model Development

2.1. Description of Previous Groundwater Flow Models

The Groundwater Management Act of 1980 established several Active Management Areas (AMAs) within the state of Arizona to address the problem of groundwater overdraft. The Phoenix AMA was established to manage withdrawals in the largest and most populous urban area in the state, which includes the cities of Phoenix, Tempe, Scottsdale, Mesa, Glendale, Peoria, and many other smaller communities. ADWR began development of a groundwater flow model for the Phoenix AMA in the late 1980's as a tool to aid in the development of a comprehensive water management plan. The model has been updated several times with the most recent version being released in early 2009. Documentation for these models can be found in Corkhill et al. (1993), Correll and Corkhill (1994), Bota et al. (2004), Corkhill et al. (2006), and Freihoefer et al. (2009).

The most recent version of the ADWR model is 3-layer modular finite difference groundwater flow model of the SRV that includes the West Salt River Valley (WSRV) subbasin, East Salt River Valley (ESRV) subbasin, Lake Pleasant subbasin, and a small portion of the Hassayampa subbasin (Figure 1). The model was developed using the United States Geological Survey (USGS) MODFLOW 2000 groundwater flow modeling code (Harbaugh et al., 2000) and was calibrated under transient conditions using annual stresses between years of 1983 and 2006. The model was calibrated to groundwater elevation data collected by the ADWR as part of basin-wide water level measurement sweeps during the winters of 1991-1992, 1997-1998, and 2002-2003.

2.1.1. Model Descritization

The ADWR model has a grid spacing of one-half mile by one-half mile with a total of 125 rows and 222 columns (Figure 2). The model has three layers representing the three major regional basin-fill aquifers within the SRV. The three major basin-fill aquifers are the Lower Alluvial Unit (LAU), Middle Alluvial Unit (MAU), and the Upper Alluvial Unit (UAU). The contacts between the units were defined based on geophysical logs, drillers' logs, geologists' logs, particle-size logs, and gravity surveys (Corkhill et al., 1993 and Freihoefer et al., 2009)(Figures 3 and 4).

The LAU (Layer 3) unconformably overlies consolidated bedrock and consists predominantly of conglomerate and gravel near the basin margins grading into mudstone and gypsiferous and anhydritic mudstone at the center of the basin. The MAU (Layer 2) overlies the LAU and consists predominantly of silt, clay, and mudstone with interbedded layers of sand and gravel. The MAU is generally finer grained than the LAU and the

UAU; however, the MAU coarsens near the margins of the valley such that it becomes difficult to distinguish from the LAU and the UAU in these areas. The MAU was differentiated from the MAU and UAU by the frequency and thickness of fine-grained materials within the basin-fill sediments. The MAU was required to contain at least 40 percent clay and/or silt and have a total thickness of at least 60 feet (Freihoefer, 2009). The UAU (Layer 1) overlies the MAU and extends upwards to ground surface. The UAU consists predominantly of gravel and sand and silt and tends to coarsen near former and present day river channels and near the margins of the valley. Although the basin-fill sediments can reach thicknesses greater than 10,000 feet, the total thickness of sediments simulated by the ADWR model was limited to the upper 3,000 feet below ground surface (bgs) since few wells exist below this depth (Freihoefer, 2009).

2.1.2. Model Boundaries

The lateral boundaries of the ADWR active model area generally coincide with the intersection of the basin-fill sediments and crystalline bedrock associated with surrounding mountain blocks. The bedrock is largely composed of consolidated granitic, volcanic, sedimentary, and metamorphic rocks that form a nearly impermeable boundary to the basins. The bedrock areas were assumed to completely impermeable and were simulated using no-flow cells in the model grid. The bedrock is also present beneath the basin-fill sediments at depths that gradually become shallower toward the margins of the basins. The bedrock underlying the basin-fill sediments was also assumed to be completely impermeable and forms the base of the model grid where the bedrock is shallower than 3,000 feet bgs.

At several locations, the margin of the active model area represents locations where the simulated basin-fill sediments are connected to basin-fill sediments from surrounding sub-basins. These include the boundaries between the following subbasins:

- ESRV subbasin and the Eloy subbasin near Florence
- ESRV subbasin and the Eloy subbasin near Santan and Sacaton
- ESRV subbasin and the Maricopa-Stanfield subbasin
- WSRV subbasin and the Hassayampa subbasin (northern boundary)
- WSRV subbasin and the Hassayampa subbasin (southern boundaries)
- Southern Lake Pleasant and northern Lake Pleasant subbasin near New River

Underflows across these boundaries were estimated based on water level gradients, flow nets, and model simulations (Corkhill et al., 1993) and were simulated with a combination of constant head and specified flux cells. Specifically, the southern boundaries between the WSRV and the Hassayampa subbasins were simulated with constant head cells, whereas all other underflow boundaries were simulated with specified flux cells.

2.1.3. Hydraulic Properties

ADWR assigned hydraulic properties to the groundwater flow model based on hydrogeologic data from aquifer testing and groundwater contamination sites, specific capacity data from the ADWR's Groundwater Site Inventory, particle size data from the USGS, and simulated model parameters from localized groundwater flow models (Correll and Corkhill, 1994). The aquifer parameters assigned to the initial versions of the model were modified during successive re-calibration events.

2.1.3.1. Hydraulic Conductivity

Horizontal hydraulic conductivities assigned to model were generally greatest for the UAU and least for the LAU. Horizontal conductivity varied spatially across the model domain due to the variable nature of the basin-fill sediments. Horizontal conductivities assigned to the UAU ranged from 2 to 198 feet per day (ft/day) and were generally greatest near the modern Salt and Gila rivers and least near the centers of the WSRV and ESRV subbasins. Horizontal conductivities assigned to the MAU ranged from 1 to 148 ft/day and were generally greatest along the margins of the subbasins and least near the centers of the subbasins. The horizontal conductivities assigned to the LAU ranged from 0.3 to 68 ft/day with a spatial distribution similar to that of the MAU.

Vertical hydraulic conductivities were assumed to have a constant ratio relative to the horizontal hydraulic conductivities. The ratios of the vertical hydraulic conductivity to the horizontal hydraulic conductivity were assumed to be 1:10 for the UAU, 1:20 for the MAU, and 1:12 for the LAU. The smaller ratio for the MAU reflects the greater proportion of fine-grained sediments in this unit. The vertical conductance (VCONT) between model layers was calculated within the model environment based on the assigned vertical hydraulic conductivities. A summary of the hydraulic properties, by model layer is provided in Table 2-1.

Table 2-1:
Summary of Simulated Hydraulic Properties

Layer	Unit	Horizontal K (feet/day)	Vertical K/ Horizontal K	Storativity	Specific Yield
1	UAU	2 – 198	1:10	-----	0.03 – 0.2
2	MAU	1 – 148	1:20	0.005	0.01 – 0.3
3	LAU	0.3 – 68	1:12	0.005	0.01 – 0.15

2.1.3.2. Storage Coefficients

The UAU was simulated strictly as an unconfined aquifer. As such, it was not necessary to assign a confined storativity to this layer. The specific yields assigned to the UAU

ranged from 0.03 to 0.2. The MAU and LAU were simulated as convertible with the ability to change from confined to unconfined when water levels fall below the top of the layer. Specific yields assigned to the MAU and LAU were generally less than those assigned to the UAU and ranged from 0.01 to 0.3 and 0.01 to 0.15, respectively. Areas with larger horizontal hydraulic conductivities also tended to have greater specific yields. The MAU and LAU were assumed to have a consistent confined storativity of 0.005 across the model domain. A summary of the hydraulic properties, by model layer is provided in Table 2-1.

2.1.4. Streams

ADWR used the Stream (STR) package in MODFLOW to simulate major streams in the active model area. Major streams included the Gila, Salt, Agua Fria, Santa Cruz, and Hassayampa Rivers and Indian Bend Wash. The Buckeye Irrigation Canal was also simulated as were discharges from the 23rd Avenue and 91st Avenue Wastewater Treatment Plants (WWTPs). These features were subdivided into 20 individual stream segments through which stream flows were assigned, routed, and combined to represent the distribution of flows though the stream network. The stream package simulates gaining and losing reaches throughout the network based on the difference in the elevation between the stream stage and the elevation of the water table and has the ability to terminate flow into the aquifer when the stream reaches zero flow.

2.1.5. Recharge

There are numerous natural and anthropogenic (human-derived) sources of recharge that contribute water to the groundwater flow system in the Phoenix AMA. Natural sources of recharge include:

- mountain front recharge
- stream infiltration
- recharge from flood flows along river courses

Anthropogenic sources of recharge include:

- agricultural recharge
- urban/turf recharge
- recharge from artificial lakes
- recharge from canals
- recharge from artificial recharge facilities
- treated wastewater flows

Anthropogenic sources of recharge are the dominant source of recharge in the valley and account for an approximately 85% of the total estimated recharge to the groundwater flow system (Freihoefer et al., 2009).

The majority of the recharge simulated in the ADWR model was applied using the RCH package. Recharge rates from each of the distinct sources were combined to create a total recharge distribution for the active model domain. Total simulated recharge rates varied from year to year depending on annual flood flow quantities, agricultural irrigation uses, land used and management changes, and quantities of artificial recharge introduced.

Recharge sources that were already simulated with the stream package were not included in the RCH package. These included leakage from the major stream courses under non-flood-flow conditions, leakage from the Buckeye Canal, and discharges from the 23rd and 91st Avenue WWTPs. Stream infiltration from the more minor stream courses (New River, Skunk Creek, Cave Creek, and Queen Creek) and flood-flow recharge from the major stream courses were included in the RCH package.

Mountain front recharge was applied along the White Tank, Sierra Estrella, and New River Mountains. Since the elevations of the mountains are generally less than 4,000 feet above mean sea level (amsl), the quantities of recharge applied were relatively small (Freihoefer et al., 2009). Agricultural recharge consists of irrigation water that percolates past the crop root zone. Since irrigation water traveling through the vadose zone can take 10 to 15 years to reach the water table, the spatial extent of irrigated lands from 1973 was used along with the location of Irrigation Grandfathered Rights (IGFRs) to estimate the amount of agricultural recharge entering the groundwater system between 1983 and 2006 (Freihoefer, et al., 2009).

Urban recharge consists of flood flow irrigation water applied to Salt River Project urban irrigation lands. Turf recharge consists of irrigation water applied to parks and golf courses. ADWR assumed that urban/turf recharge was constant over time. Artificial lake recharge is from lakes and ponds constructed in golf courses and commercial/residential developments. Artificial lakes greater than 10 acres in size were simulated in the ADWR model.

Canal recharge results from water seeping through the bottom of canals. ADWR assigned canal recharge volumes based on whether the canal was lined or unlined (Freihoefer et al., 2009). Unlined canals included the San Carlos Irrigation Project (SCIP) canals, the Buckeye Irrigation Canal, and the unlined portions of the Salt River Project (SRP) Grand Canal. Lined canals included canals in the SRP system, Roosevelt Irrigation District, Roosevelt Conservation District, Central Arizona Project, and the Maricopa Water District.

Artificial recharge facilities are permitted facilities where effluent and other sources of water are allowed to infiltrate though permeable soils and recharge the water table. A total of 29 artificial recharge sites, including the Avondale Recharge Facility, are simulated in the ADWR model.

2.1.6. Evapotranspiration

Evapotranspiration occurs in areas where phreatophyte plant species are present. These species are primarily limited to the Salt and Gila River riparian corridors where depths to groundwater are less than 20 to 30 feet bgs. Evapotranspiration was applied to the ADWR model along the Salt and Gila River corridors with the assigned rates based on the density of phreatophyte growth as determined by analysis of LANDSAT digital images (Corkhill et al. 1993). Higher evapotranspiration rates were assigned to areas with greater densities of phreatophyte growth, and lesser rates were assigned to areas with lesser densities of phreatophyte growth. Evapotranspiration was assumed to cease where groundwater elevations were below 30 feet bgs. Evapotranspiration rates applied to individual grid cells ranged from 0 to 782 acre-feet per year (acre-feet/year).

2.1.7. Pumping

Annual groundwater withdrawals for agricultural, municipal, industrial, and various other purposes were simulated in the ADWR model using the WEL package in MODFLOW. Annual pumping rates for the years from 1984 to 2006 were obtained from ADWR's Registry of Grandfathered Rights (ROGR) database (Freihoefer at al., 2009). Annual pumping rates for 1983 were estimated assuming a linear trend between the 1984 ROGR pumping rates and the pumping rates reported between 1975 and 1979. Pumping was distributed to the individual model layers based on the depth of the perforated intervals (if available), well depth if perforation data was not available, or on average well depth in the given area if no information was available (Freihoefer et al., 2009). Groundwater pumpage was the dominant means by which water exited the groundwater flow system (Freihoefer et al., 2009), with annual model-wide pumpage ranging from approximately 620,000 to 1,330,000 acre-feet between 1983 and 2006.

2.2. Model Refinement

The purpose of developing a groundwater flow model was to create a tool capable of simulating potential water supply alternatives being considered to meet the needs of the City's water system. In order to adequately simulate those alternatives, a model with sufficient detail at the local-scale was necessary to provide a reliable representation of groundwater flow conditions in and around the water system. The ADWR groundwater flow model is a regional-scale model with relatively coarse grid spacing. Though regional models can simulate large-scale flow conditions relatively well, they may lack the resolution necessary to adequately simulate local-scale conditions and may contain

biases and inaccuracies within given areas of the model domain. Existing models must be evaluated to ensure that the nature of the model is appropriate for its intended use.

The ADWR groundwater flow model was evaluated to determine its ability to simulate local-scale conditions in and around the City's water system. To be considered appropriate for the intended use, it was determined that the ADWR model had to be able to simulate the following attributes of the water system with sufficient detail:

- the physical layout of the City's water system (namely the locations of the City's groundwater wells and recharge basins)
- the geologic layering in vicinity of the water system
- the groundwater elevations in the vicinity of the water system
- the groundwater flow patterns in the vicinity of the water system

Based on this is evaluation, it was determined that the ADWR could not fully simulate the attributes Avondale water system with sufficient detail and that some refinement of the model was necessary. The greatest shortcoming was the coarseness of the model grid in the Avondale area, which would have required simulating multiple wells with the same grid cell. The grid cell dimensions were also much larger than the dimensions of the City's recharge basins. Use of the existing ADWR model would have resulted in an insufficient resolution of groundwater elevations and flow paths in the vicinity of the water system.

Refinement of the ADWR flow model was deemed necessary to adequately simulate the potential water supply alternatives. Refinements were made with the intent of maintaining as much of the original character of the ADWR model as possible while still providing sufficient local-scale detail to fully represent attributes of the Avondale water system. The refinements made to the ADWR model, and the basis for those refinements are discussed in the following sections.

2.2.1. Physical Description of the Avondale Water System

The City receives allocations of surface water from the Salt River Project (SRP) and Central Arizona Project (CAP) canal systems. Following treatment at the Crystal Garden Wetlands, the water is recharged into the groundwater system for storage, and then extracted by the City's permitted recovery wells. In addition to recovered water, the City extracts a small amount of water that is not considered recovered water. The City's water system currently includes 17 existing groundwater wells (Table 2-2). Two of the wells are used for irrigation purposes, and three of the wells are currently inactive due to water quality issues. The City also has six wells that are planned for completion in the near future.

Table 2-2:
Summary of Avondale Groundwater Wells

Well ID	Use	Pumping Capacity (gpm)[1]	Depth (ft-bgs)	Perforated Interval (ft-bgs)
1	Inactive		456	244-264, 386-398
5	Irrigation	275	500	200-480
6	Drinking	1,550	608	364-604
7	Drinking	1,550	530	320-520
8A	Drinking	2,000	645	289-635
10	Drinking	2,200	866	200-866
11	Drinking	1,500	618	100-240
12	Drinking	2,000	458	200-867
14	Inactive	1,000	560	370-550
15	Drinking	700	800	370-530
16	Drinking	2,200	570	150-190, 210-550
16B	Irrigation	650	335	73-173
17	Drinking	1,200	710	460-670
18	Drinking	2,100	800	150-650
19	Drinking	1,450	650	150-260, 300-550
20	Planned	1,000	810	299-570, 590-800
21	Inactive	1,820	580	340-440, 480-560
22	Planned	-	600	300-420, 440-560
23	Drinking	1,260	403	148-359
24	Planned	650	640	440-600
25	Planned	-	560	340-420, 440-540
26	Planned	2,200	-	-
28	Planned	-	-	-

Notes:
(1) Rates were determined from pumping records or initial estimates provided by City; refer to the Water Infrastructure Master Plan update for most recent pumping capacities.

Water is recharged to groundwater system at the Avondale Recharge Facility, New River-Agua Fria River Underground Storage Project site, the Agua Fria Recharge site, and the Hieroglyphics Recharge site. The Avondale Recharge Facility is wholly owned by the City, whereas at the remaining sites, recharge capacities are only partially owned or leased. The soils underlying the recharge sites are permeable such that stored surface water readily percolates downward into the groundwater system. The locations of the City's groundwater wells and the Avondale Recharge Facility are depicted on Figure 5.

A Study Area was defined for the purposes of the potential water supply alternatives evaluation (Figure 5). The Study Area surrounds the portion of the City's water service area that overlies the permeable basin-fill sediments (the portion of the service area extending south into the Sierra Estrella was excluded) and is equivalent to the Study Area defined for the Water Resource Master Plan Update (Malcolm Pirnie, 2010). The Study Area includes all areas that will likely be considered for future groundwater wells. The Study Area also extends somewhat beyond the boundaries of the City's water service area since pumping from the wells will influence the groundwater flow system for some distance surrounding the actual physical locations of the wells. Refinements to the groundwater flow model are focused on reproducing groundwater flow conditions within the defined Avondale Study Area.

2.2.2. Model Grid

The grid cells sizes in the existing ADWR groundwater flow model covered an area of one-quarter of a square mile across the entire model domain (Figure 2). These grid cell dimensions were determined to be inadequate to simulate the Avondale water system in detail since many of the groundwater wells would have fallen within the same cell and the Avondale Recharge Facility covered a small portion of single cell. To improve the resolution of the model, the grid cell sizes within the Study Area were reduced to an area of one-sixteenth of a square mile. The cell sizes were reduced by sub-dividing the existing cells into quarters such that the edges of the group of four quarter cells were maintained at the same locations as the edges of the original cell. This allowed direct importation of many of the model properties from the ADWR model to the refined grid without spatial modifications. Immediately outside of the Study Area, the grid dimensions were telescoped outwards such that the original ADWR grid cell size of one-quarter of a square mile was maintained in areas away from the Study Area (where less detail was necessary). This resulted in some minor spatial modification in the imported properties for the rows and columns that were telescoped. Telescoping the model grid allowed for detailed simulations within the Study Area while not greatly increasing the computational complexity of the model simulations.

2.2.3. Model Boundaries

The effect of the Avondale water system on the groundwater flow system is relatively localized compared to the size of the ADWR model domain. Pumping from the Avondale water system has no significant influence outside the WSRV subbasin, such that simulation of the entire ADWR model domain was not necessary. Decreasing the size of the model domain also provides the benefit of decreasing the computational complexity of the model simulations.

The domain of the refined model was reduced from the size of the original ADWR model domain to include only areas within the WSRV subbasin (Figure 6). The ESRV and Lake Pleasant subbasins were not explicitly included in the refined model; however, underflow from these subbasins was simulated by the addition of new inflow/outflow boundaries at the borders between these basins and the refined active model area (Figure 7). The borders between the subbasins were convenient places to locate the new model boundaries since the extent of the basin-fill sediments narrows at these locations, and the groundwater flows across these narrow points can be estimated relatively easily. The new inflow/outflow boundaries were also sufficiently distant from the Study Area such that they did not artificially influence groundwater flows within the Study Area.

Five new inflow/outflow boundaries were created at the margins of the refined model grid at the locations shown in Figure 7. Three of the boundaries simulated inflows from the Lake Pleasant subbasin, one boundary simulated inflows and outflows from the ESRV subbasin between the Phoenix Mountains and South Mountain, and one boundary simulated inflows and outflows from the Maricopa-Stanfield subbasin between South Mountain and the Sierra Estrella. The new boundaries were constructed to reproduce the simulated flows from the original ADWR model as closely as possible.

Simulated flows from the ADWR model at the new boundary locations were investigated by reviewing the cell-by-cell water budgets from a working version of the model. Upon inspection of the water budgets for the model cells corresponding to the new boundary locations, it was apparent that both the simulated groundwater flow quantities and simulated groundwater elevations were changing over time such that a transient boundary condition would be required to closely replicate the original ADWR flows. Transient specified head boundary cells were used since they provided the ability to simulate both the changing groundwater elevations and changing groundwater flows. The simulated groundwater elevations for each of the annual stress periods from the ADWR model were exported and assigned to the new boundary cells in the refined model. Once the refined model was fully constructed, the cell-by-cell flows from the new boundary cells in the refined were evaluated as part of the calibration/verification process to ascertain whether the new cells adequately approximated the original ADWR flows.

In addition to the new inflow/outflow boundaries, the refined model was also constructed with inflow/outflow boundaries at three locations where the WSRV subbasin borders the Hassayampa subbasin (Figure 7). These boundaries were also present in the original ADWR model and were not modified except for the minor adjustments that occurred where the grid dimensions were changed. Similar to the ADWR model, a combination of constant head cells and specified flux cells were used to simulate these boundaries.

2.2.4. Model Layers

The City has conducted several local sub-surface investigations within the Study Area in recent years associated with the expansion of their water system. Sub-surface investigations have also been conducted by surrounding communities and other private entities. The vertical descritization of the model layers in the original ADWR model were evaluated to determine if refinement was necessary to incorporate new geologic data generated from these investigations.

ADWR documents indicate that the vertical descritization of the ADWR model was recently updated in 2005 to reflect geologic data collected since the development of the first version of the groundwater flow model in 1986 (Corkhill et al., 2006). A total of approximately 15,000 registered wells were identified as being installed within one mile of the ADWR active model area between 1986 and 2005 (Corkhill et al., 2006). From the 15,000 new wells, boring logs of various quality (including drillers' logs, geologists' logs, particle size logs, and geophysical logs) were found for approximately 860 of the wells, including numerous logs from wells located in the Avondale Study Area. These borings logs were used to update the elevations of the contacts between the UAU, MAU, and LAU. The 2005 geologic update represents the most recent and complete geologic interpretation of the SRV.

Since a comprehensive revision of the vertical descritization of the ADWR groundwater flow model was recently completed, the model was considered to be up-to-date and to incorporate the majority of the geologic data available for the WSRV and the Study Area. However, some additional geologic data was available from groundwater wells installed by the City near and following the time of the 2005 geologic update. These included City Wells 8A, 16, 19, 20, 21, 23, and 24. Consultant reports summarizing the drilling and installation of these wells were reviewed and the interpreted elevations of the contact between the UAU and MAU (the boreholes were terminated prior to reaching the LAU) were compared to the simulated contact elevations in the groundwater flow model.

The interpreted contact elevations from Wells 8A, 16, 19, 20, 21, 23, and 24 and the corresponding simulated elevations in the groundwater flow model are summarized in Table 2-3. For the majority of the wells, the interpreted contact elevation is similar to the simulated contact elevation. The exceptions are for wells 20 and 21, which each show a discrepancy of approximately 100 feet. However, since the two wells are located at

opposite ends of the Study Area and since the contact between the UAU and MAU is often gradational and a matter of interpretation, it was determined that modification of the vertical descritization of the groundwater flow model to account for these two sparse and physically distant data points was not warranted and was unlikely to significantly influence the model results. The vertical descritization from the ADWR groundwater model was therefore maintained for the refined groundwater flow model.

Table 2-3:
Contact Elevations for Recent Avondale Groundwater Wells

Well ID	Interpreted Contact Elevation (ft-amsl)	Simulated Contact Elevation (ft-amsl)	Source
8A	555	600	CCA, 2004
16	620	606	URS, 2005a
19	585	606	URS, 2003
20	565	674	CCA, 2006
21	525	621	AMEC, 2007
23	637	615	URS, 2005b
24	590	602	AMEC, 2006

2.2.5. Hydraulic Properties

The hydraulic properties assigned to the ADWR model (hydraulic conductivity, storativity, specific yield) were also evaluated to determine if further refinement within the Study Area was necessary. Aquifer testing data from the recently installed Avondale supply wells were reviewed to determine their consistency with the simulated values in ADWR model. The hydraulic properties estimated in the consultant reports for wells 8A, 16, 19, 20, 21, 23, and 24 are summarized Table 4.

From Table 2-4, it is apparent that the majority of the wells for which aquifer testing data are available are perforated across both the UAU and the upper portion of the MAU. The hydraulic properties estimated for these wells are, therefore, composite values for the two units rather than the true values for either of the individual units. Only wells 23 and 24 have perforations within a single unit and have estimated hydraulic properties that are representative of the individual units. Because of the sparseness of representative new data points (one data point each for the UAU and MAU), the hydraulic properties from the ADWR model were also maintained in the refined model. Only minor changes to the spatial distribution of the hydraulic properties from ADWR model occurred where it was

necessary to telescope the refined grid. The hydraulic properties assigned to the refined model grid are depicted on Figures 8 through 13.

Table 2-4:
Hydraulic Properties for Recent Avondale Supply Wells

Well	Perforated Unit	Transmissivity (gpd/ft)	Aquifer Thickness (feet)	Hydraulic Conductivity (feet/day)	Storage Coefficient	Source
8A	UAU & MAU	117,200	503	31	-	CCA, 2004
16	UAU & MAU	133,000	461	33	0.0003	URS, 2005a
19	UAU & MAU	84,800	464	24	-	URS, 2003
20	UAU & MAU	43,700	631	9	-	CCA, 2006
21	UAU & MAU	116,400	498	31	-	AMEC, 2007
23	UAU	142,000	245	77	-	URS, 2005b
24	MAU	29,513	450	9	-	AMEC, 2006

2.2.6. Streams

The major streams in the ADWR model were subdivided into 20 individual stream segments and simulated with the MODFLOW stream package. The stream package combines, routes, and calculates the simulated flows through the stream network. Importation of the stream package from the ADWR model was attempted; however, the complexity of the parameters needed to define the stream network made transferring the existing network into the refined model grid unfeasible. Complete reconstruction of the stream package was necessary in the refined model.

The stream package was reconstructed by estimating the values of the underlying parameters that were used to define the stream package in the ADWR model. These values were applied to a new network of stream cells with locations defined based on the locations of the streams from ArcGIS hydrology shapefiles imported and overlain on the model grid. The goal was to reproduce as closely as possible the original streamflows and streambed leakages from the ADWR model. The methods used to reconstruct the stream package are described in the following paragraphs.

2.2.6.1. Segments

The stream cells were divided into fourteen individual segments with segment boundaries coinciding with those from the original ADWR model (Figure 14). The exception was for those segments that crossed the new model boundaries defined between the WSRV subbasin and the ESRV, Lake Pleasant, and Maricopa-Stanfield subbasins. These stream segments were truncated at the location new model boundary. Segments that were

truncated included segment 1 (Agua Fria River at the border of the Lake Pleasant subbasin), segment 3 (Gila River at the border of the Maricopa-Stanfied subbasin), and segment 5 (Salt River at the border of the ESRV subbasin).

2.2.6.2. Stream flows

In the stream package, incoming stream flows are assigned at the heads of the upper-most stream segments and are routed and combined with tributaries in the downstream direction. Water also moves into and out of the streams to/from the aquifer based on the relative stage of the river and the water table. With the reduction of the active model area, the upper-most stream segments in the refined model no longer corresponded to the upper-most stream segments in the original ADWR model.

To be able to closely reproduce the stream flows from the ADWR model, the simulated water budgets from the original ADWR model were used to assign the incoming stream flows in the refined model. The new incoming flows were calculated by adding the incoming stream flows from the ADWR model to the net change in flow into/out of the streams between the head of the upper most stream segment in the ADWR model and the new head of the upper most stream segment in the refined model. This resulted in incoming flows in refined model that were approximately equal to the flows at same point in the original ADWR model. Since stream flows in the ADWR model changed during each stress period, the incoming flows in the refined model had to be recalculated for each stress period.

2.2.6.3. Stream Stage

The stage of the stream relative to the water table elevation controls whether water leaves the stream and enters the aquifer or whether water exits the aquifer and enters the stream. The stream stage is calculated by the model using simple channel hydraulics and Manning's equation. Calculation of the stream stage requires definition of the stream width, streambed bottom elevation, streambed top elevation, stream sinuosity, Manning roughness coefficient, and initial stream stage.

The stream width, sinuosity, and Manning's roughness coefficient are constant for each stream segment. Values for these parameters were taken directly from the ADWR model and assigned to the corresponding segments in the refined model. The streambed bottom elevation, streambed top elevation, and initial stream stage change gradually across each stream segment as the simulated streams drops in elevation in the downstream direction. These parameters were applied to the stream cells in the refined model by first assigning the streambed and stage elevations to the beginning and end of each stream segment. The elevations for the cells in the interior of the stream segment were then calculated within the model environment using linear interpolation methods. The elevations applied to the beginning and end of each segment were approximately equal to those from corresponding locations in the ADWR model

The slope of each stream segment in the refined model was calculated within the model environment by dividing the difference between streambed top elevation at the beginning and end of each segment by the distance of the segment and then multiplying by the sinuosity factor. Comparing the slope calculated from the refined model with the slope from the ADWR model provided an independent check that these parameters were applied correctly. Although the calculated slopes for the stream segments could not be reproduced exactly, the slopes were very similar indicating the refined streambed elevations and sinuosities closely approximated those from the original ADWR model.

2.2.6.4. Conductance

The streambed conductance controls the volume of water that will enter or exit the steam under the influence of a hydraulic gradient between the stream and the aquifer. The streambed conductance is the product of the hydraulic conductivity of the streambed sediments and the length and width of the stream segment divided by the thickness of the streambed sediments. Since the underlying parameters used by ADWR to calculate the conductance were not reported and could not be obtained from the working version of the model, the streambed conductance values applied to individual model cells could not be exactly reproduced. The conductance values from the original ADWR model were instead approximated by attempting to closely reproduce the total conductance of each stream segment. The conductance values were assigned to the refined model grid by applying a value for the conductance per foot of stream length, and iteratively adjusting that value until the total stream segment conductance from the ADWR model was closely approximated. The conductance for each stream cell in the segment was calculated within the model environment by multiplying the conductance per foot of stream length by the total length of stream intersecting the given cell. This process was performed for each stream segment.

2.2.7. Recharge and Evapotranspiration

The total recharge applied to the RCH package in the ADWR model was from a combination of distinct recharge sources. These distinct recharge sources included mountain front recharge, recharge from flood flows along major river courses, recharge from stream infiltration, agricultural recharge, urban/turf recharge, recharge from artificial lakes and canals, and recharge from artificial recharge facilities. The total recharge distribution applied to the ADWR model was maintained in the refined model except for minor modifications occurring where the model grid was telescoped (Figure 15). The evapotranspiration distribution was also unchanged except for minor modifications where the grid was telescoped (Figure 16).

2.2.8. Wells

Pumping from the ADWR model was generally maintained in the refined model, but with some modifications. Since grid cells from the original ADWR model were sub-divided within the Study Area, pumping had to be redistributed within the subdivided cells. For the sub-divided cells, wells contained in the original ADWR grid cells were moved to the northwestern-most quarter cell from the group of four quarter cells corresponding to the original ADWR cell. This resulted in a slight modification of the locations of those wells, but the total pumping rates from the wells were not modified. This was deemed acceptable to simulate the regional distribution of pumping in the model.

The simulation of pumping from the City of Avondale required greater resolution. Maps of the exact Avondale supply well locations were overlain on the model grid, and new simulated wells were created in the refined grid cells corresponding to those locations. For the Avondale supply wells that already existed in the ADWR model, the existing simulated Avondale supply well was identified, and the pumping rates were transferred to the new simulated well. This resulted in movement of the Avondale supply wells to their correct location with no net change in pumping.

2.2.9. Calibration/Verification

Once the refined groundwater flow model was fully reconstructed, the model underwent a calibration/verification process. Since most of the character of the original ADWR model was maintained in the refined model, the calibration/verification process focused on closely reproducing the water budgets from the original groundwater flow model and achieving model errors similar to or better than the ADWR model within the refined model domain. The calibration/verification also focused on generally reproducing groundwater flow patterns within the Study Area. The calibration/verification process is described in the following sections.

2.2.9.1. Flow Budgets

The first step in the calibration/verification process was comparing water budgets from the refined model to the water budgets from the original ADWR model. Close agreement in the water budgets from the two models indicates that the model parameters and boundary conditions were adequately redescritized in the refined model (though some differences are to be expected due to the modifications made to the model). Flows from each pertinent individual water budget component were tabulated and are summarized in Appendix B. The percent differences between the water budget components were calculated and were used to quantify the discrepancies between the two models.

As discussed in Section 2.1.2, five new underflow boundaries were created at the margins of the refined model grid (Figure 7) to simulated underflow from the Lake Pleasant,

ESRV, and Maricopa-Stanfield subbasins. For documentation purposes the new model boundaries were numbered in a clockwise fashion with locations summarized below:

- Boundary 1: Border with Lake Pleasant subbasin – Agua Fria River Valley
- Boundary 2: Border with Lake Pleasant subbasin – New River Valley
- Boundary 3: Border with Lake Pleasant subbasin – Skunk Creek Valley
- Boundary 4: Border with ESRV subbasin
- Boundary 5: Border with Maricopa-Stanfield subbasin

The flows from the new boundaries were compared to the cell-by-cell flows from the corresponding active cells in the ADWR model to determine how closely the original flows were reproduced in the refined model (Appendix Table B-1).

From Appendix Table B-1, all simulated inflows from the new model boundaries were within three percent of the cell-by-cell flows from the corresponding cells in the ADWR model. Simulated outflows had larger percent discrepancies largely because of the small quantities of outflow occurring. The close agreement between the flows in the refined and ADWR models indicates the new model boundaries in refined model were properly defined.

Three additional boundaries along the western margin of the refined model were maintained from the original ADWR model. These boundaries include:

- Boundary 6: Border with Hassayampa Subbasin – Southern Hassayampa River Valley
- Boundary 7: Border with Hassayampa Subbasin – Gila River Valley
- Boundary 8: Border with Hassayampa Subbasin – Northern Hassayampa River Valley

Simulated inflows and outflows from these boundaries are also summarized in Appendix Table B-1. Both simulated inflows and outflows across boundary 6 are within five percent of simulated inflows and outflows from the ADWR model. Simulated outflows across boundary 7 are slightly larger than in the ADWR model, but still within nine percent. The slight increase in outflows across boundary 7 is attributed to the modifications necessary to reconstruct the stream package, which includes cells that intersect boundary 7. Boundary 8 was defined by specified flux cells in both the refined model and the ADWR model. The flows specified to this boundary were equivalent to those in the ADWR model. On the whole, flows across the refined model boundaries closely approximated the flows from the original ADWR model.

Comparable model-wide flow budgets from the refined model were also compared to the cell-by-cell flow budgets for an equivalent area from the original ADWR model. These

flow budgets are summarized in Appendix Table B-2. The most significant difference between the refined model flow budgets and the ADWR flow budgets was within the stream package. This was expected given the complexity of the stream package and the difficulty in closely reproducing the parameter distribution from the ADWR flow model in the refined model. Stream leakage into the aquifer increased approximately thirteen percent and flows from the aquifer to the stream decreased approximately sixteen percent. The additional flow from the streams appears to result in increased discharge from the evapotranspiration package (approximately nineteen percent) and an increase in storage (approximately ten percent). The remaining flow budget components were within five percent of the original ADWR model. Further modifications to the stream package were not attempted since the redescritization of the streams resulted in improved model errors within Study Area.

The model-wide flow budgets from the refined model were also evaluated to determine the percent discrepancies between simulated inflows and simulated outflows. The complete flow budgets from the refined model are summarized in Appendix Table B-2. The percent discrepancies between the inflows and outflows for all stress periods were less than one one-hundredth of one percent indicating a numerically stable solution.

2.2.9.2. Groundwater Elevations

The ADWR model was calibrated under transient conditions using annual stresses between years of 1983 and 2006. The model was calibrated to groundwater elevation data collected by the ADWR as part of basin-wide water level measurement sweeps during the winters of 1991-1992, 1997-1998, and 2002-2003. Upon inspection of the residual errors (differences between the simulated water level and the measured water level) from the ADWR model (Freihoefer et al., 2009), it was observed that although the model simulated heads over the WSRV subbasin relatively well, the model tended to over-simulated groundwater elevations in the center of the subbasin and under-simulate groundwater elevations in the southern and southeastern portions of the subbasin. The Avondale Study Area falls within a portion of the subbasin where groundwater elevations tended to be under-simulated.

Three types of statistical methods are widely used to quantify model errors. These include measurement of the mean error (ME), absolute mean error (AME), and the root mean squared error (RMSE). These methods provide the following information about the model error:

- ME - indicates whether and to what degree the model is under or over-simulating groundwater elevations.
- AME - quantifies how closely simulated elevations are to measured elevations.
- RMSE - measures the spread of the errors around the mean value.

The documented simulated groundwater elevations, measured groundwater elevations and residuals from ADWR model for both the WSRV subbasin the Study Area were obtained and tabulated to quantify the errors in ADWR model within these sub-regions (ADWR, 2009). The unweighted residual errors for the 1991-1992, 1997-1998, and 2002-2003 time periods are tabulated in Appendix Tables C-1 and C-2. The resulting ME, AME, and RMSE for each time period are also provided in these tables and are summarized in Table 2-5.

Table 2-5:
Unweighted Residual Error Summaries for the ADWR Model

Year/Error Measurement Type	WSRV Sub-basin	Study Area
1991/1992		
ME (feet)	-4.94	-9.12
AME (feet)	19.31	11.01
RMSE (feet)	27.41	12.95
1997/1998		
ME (feet)	-2.34	-11.88
AME (feet)	24.66	15.35
RMSE (feet)	34.02	16.61
2002/2003		
ME (feet)	-0.12	-9.21
AME (feet)	22.09	13.49
RMSE (feet)	29.83	16.60

From the ME values in Table 2-5, it is apparent that within the WSRV subbasin as whole, the ADWR model slightly under-simulates groundwater elevations (negative values indicate under-simulation). Within the Avondale Study Area, however, the magnitude of under-simulation is greater. The mean difference between simulated elevations and measured elevations (AME) in the Study Area ranges from 11 to 15 feet, with under-simulated residuals resulting in the majority or the error. While the model errors are small relative to the 3,000 foot thickness of the simulated basin-fill sediments in the model, it was determined that any changes in simulated groundwater water elevations resulting from refinement of the ADWR model should result in a lesser under-simulation of groundwater elevations within the Study Area to be considered acceptably calibrated.

The groundwater elevation measurements used to calibrate the ADWR model were imported into the refined model to the quantify errors in the refined model relative to those from the ADWR model. The calibration/verification of the refined model was slightly more generalized than the original ADWR model in that all of the measured wells were assumed to have perforated intervals within an individual model layer. When

necessary, ADWR proportioned the monitored wells across multiple layers based on the percentage of the perforated interval in each layer. However, data and assumptions used to proportion the wells were not available and the assumed percentages could not easily be imported to the refined model. Therefore, wells with perforated intervals across multiple layers were assigned to the layer containing the greatest percentage of perforations as defined by ADWR. Since vertical gradients in the model are relatively small, this simplification should have minimal influence on the residuals. The unweighted residual errors for the 1991-1992, 1997-1998, and 2002-2003 water level sweeps are tabulated in Appendix Tables C-3 and C-4 and are summarized in Table 6. The unweighted residuals are also depicted graphically in Figure 17 through 19. Similar to the ADWR model, the refined model tends to under-simulated groundwater elevations in the center of the WSRV subbasin and over-simulate elevations in the southern and southeastern portions of the basin.

Close-up views of the refined model residuals from the Avondale Study Area are depicted in Figures 20 through 22. The greatest under-simulation in the Study Area occurs in a small area south of Interstate 10 and along the Agua Fria River, and the greatest over-simulation occurs in a small area near the point where the Agua Fria River enters the Study Area. The residuals within the Study Area are generally smaller relative to those from the WSRV subbasin as a whole.

Table 2-6:
Unweighted Residual Error Summaries for the Refined ADWR Model

Year/Error Measurement Type	WSRV Sub-basin	Study Area
1991/1992		
ME (feet)	-3.08	-4.99
AME (feet)	18.75	8.24
RMSE (feet)	27.34	10.02
1997/1998		
ME (feet)	-0.17	-7.08
AME (feet)	23.77	11.31
RMSE (feet)	33.77	13.22
2002/2003		
ME (feet)	2.38	-3.70
AME (feet)	20.47	11.26
RMSE (feet)	28.66	13.77

In comparing Table 2-6 to Table 2-5, it is apparent that the reconstruction and refinement of the ADWR model resulted in similar model errors across the WSRV subbasin and significantly improved errors within the Study Area. Across the West Salt River Valley

subbasin, model errors became slightly less under-simulated and the mean difference between simulated and error improved by one-half foot to one-and-a-half feet for the three groundwater elevation measurement periods. Within the Study Area, a greater improvement in model error occurred. Groundwater elevations became 40 to 50 percent less under-simulated, and the mean difference between simulated and measured groundwater elevations improved several feet. The small increase in leakage from the reconstructed stream package resulted in slightly increased groundwater elevations, especially along the streams in the southern portion of the WSRV subbasin. These areas correspond to areas in the original ADWR model where the greatest under-simulation of groundwater elevations occurred. The result is an improved simulation of groundwater elevations within the Study Area. Since the refined model exhibited improvements in both model-wide errors and errors within the Study Area, the refined model was considered adequately calibrated to groundwater elevations.

2.2.9.3. Hydrographs

The ability of the model to simulate transient changes in groundwater elevations over time was also evaluated. Changes in model-simulated groundwater elevations were evaluated by constructing hydrographs of the model simulated elevations and comparing those to hydrographs of measured water levels from monitoring wells within the Avondale Study Area.

ADWR periodically collects periodic measurements of water levels in numerous index wells across the state of Arizona. Eleven of the index wells are located within the Avondale Study Area (Figure 23). Water level data from the eleven index wells were obtained and used to construct groundwater elevation hydrographs for the time period covered by the model simulations (1984 – 2006). These groundwater elevation data were plotted alongside simulated groundwater elevations at the end of each simulated time step from corresponding locations within the model domain (Figures 24 through 29).

The hydrographs show that the model simulates changes in groundwater elevations relatively well. Though some over and under-simulation of water levels is apparent in the hydrographs (as discussed in Section 2.2.9.2), there is little to no divergence between simulated and observed groundwater elevations over time. The refined model was able to simulate the general decrease in groundwater elevations occurring during the simulation period as well as relative maximums observed in 1985-1986 and 1993 and relative minimums observed in 1990-1991 and 2004 (water level data from some of the index wells were too sparse to exhibit these maximums and minimums).

2.2.9.4. Flow Patterns

The flow patterns produced by the refined groundwater flow model were also evaluated to determine if they adequately represented the real flow patterns within the aquifer. Though a highly detailed replication of the flow patterns cannot be expect with such an

expansive model, it was important that the general flow patterns within the Study Area be reproduced. To compare simulated groundwater flow patterns to actual flow patterns, groundwater flow elevation contours from the 1997/1998 groundwater elevation measurement sweep (adapted from RBF Consulting, 2002) are overlain on simulated elevation contours from the same period (Figure 30).

Figure 30 shows that the flow patterns within the Study Area are generally reproduced by the refined model. The general southeast to northwest groundwater flow direction is apparent in the simulated groundwater elevation contours. The transition to a more northward flow direction in the northwestern portion of the study area and the presence of a local cone-of-depression is also apparent. The greatest discrepancy between the actual and simulated contours occurs in the central and east-central portion of the groundwater flow model where the actual groundwater elevation contours bow outward to the northwest. The simulated contours in this area exhibit a less erratic and more generalized pattern. The more generalized representation of the groundwater flow patterns in the Study Area is acceptable for the purposes of the potential water supply alternatives evaluation with the caveat that a detailed, localized replication of groundwater flow patterns cannot be expected.

2.2.9.5. Summary

The refined groundwater flow model was considered to be acceptably calibrated/verified based on its ability to:

- Closely approximate the groundwater flow budgets from the ADWR model.
- Exhibit model errors that were similar to or improved from those from the ADWR model
- Approximate the transient changes in groundwater elevations over time
- Generally simulate groundwater flow patterns within the Study Area

The refinements to the groundwater flow model allow for a more detailed simulation of the groundwater conditions in vicinity of the Avondale Water System than was possible with the more regional ADWR model. Following construction, refinement, and calibration/verification, the model was used to simulate the various proposed water supply alternatives for the Avondale water system. A detailed description of those simulations is provided in the following sections.

3. Alternative Simulations

3.1. General

Once calibrated and verified, the refined groundwater flow model was used to predict the influence of several potential water supply alternatives being considered by the City on the groundwater flow system in the Avondale Study Area and within the WSRV subbasin. The following sections describe the alternatives simulated, assumptions related to future stress conditions, and methods used to implement the simulations. Results from the simulations and their implications relative to the future of the Avondale Water System are also discussed.

3.2. Drivers

A number of factors have a bearing on the favorability of potential water supply alternatives. These include cost, the reliability of the resource, infrastructure needs, operational and regulatory requirements, public perception, etc. However, the primary considerations for the Avondale water system relative to a source water standpoint are the ability to meet demands, water quality, and the sustainability of the groundwater resource.

Foremost was the ability of the alternative to meet demands within the Avondale Water System. Avondale is experiencing considerable growth in distribution area and water demands are projected to gradually increase from an average day demand of 12.9 mgd in 2010 to average day demand of 26.4 mgd at the end of the 2050 planning period (Chapter 6 of Water Resource Master Plan). The reliable supply (achieving maximum day demands with 75% of the system design capacity) required is projected to be 58.1 mgd in 2050, which results in additional raw water needs of approximately 18.6 mgd (Appendix E of Water Resource Master Plan). If it assumed that all of the additional need is to be supplied by groundwater wells, approximately 11 new wells (assuming 1,200 gpm per well) beyond those currently operating or planned would be required to meet the additional need.

Groundwater quality was also a primary consideration. Water quality within the Avondale study area is variable with many areas exhibiting concentrations that exceed primary and secondary regulatory standards. Primary drinking water standards are legally enforceable standards that apply to public water systems, whereas secondary standards are non-enforceable guidelines for contaminants that cause adverse cosmetic or aesthetic effects. Exceedence of drinking water standards results in the need for costly, long-term treatment systems and increased rates for customers.

The primary water quality parameters of concern are total dissolved solid (TDS), nitrate, and arsenic. These three parameters have historically been problematic for some of the City's existing groundwater wells. Historical water quality data from groundwater wells in the Avondale Study Area were used to construct a water quality favorability map (Figure 31). Though water quality varies with depth, the map provides a general representation of areas where favorable or unfavorable water quality can be expected. Areas with concentration in excess of 1,000 milligrams per liter (mg/L) TDS, 10 mg/L nitrate, or 10 micrograms per liter (ug/L) arsenic were considered unfavorable. Areas where the concentrations of all three of these parameters were less than these limits were considered favorable.

Contaminant releases from industrial facilities were also a primary concern. Several known contaminant plumes exist within or in close proximity to the Avondale study area including at the Phoenix-Goodyear Airport (PGA) North Superfund Site, The PGA South Superfund Site, The Western Avenue Water Quality Assurance Revolving Fund (WQARF) site, and the West Van Buren WQARF site. The major contaminants emanating from these facilities are as follows:

- PGA-North - Trichloroethene (TCE) and perchlorate
- PGA-South - TCE and chromium.
- Western Avenue - Perchloroethene (PCE)
- West Van Buren - PCE, TCE, 1,1-dichloroethane (1,1 DCA), cis-1,2-dichloroethene (cis-1,2-DCE), 1,1-dichloroethene (1,1 DCE), and chromium.

The approximate extents of these contaminant plumes (ADEQ, 2009a, ADEQ, 2009b, ADEQ, 2009c, ADEQ, 2009d) are plotted on Figure 31. The exception is the West Van Buren plume, which currently does not extend into the Avondale Study Area. This plume is located in the western portion of Phoenix and extends westward to approximately 75th Avenue. Areas in close proximity to these plumes were generally not considered for potential new supply well locations.

Sustainability of the groundwater resource was also a primary consideration. Expansion of the Avondale water system must proceed in manner that does not cause excessive drawdowns in the aquifer system or adversely impact other users of the resource. From an operational perspective, water levels must also be maintained above the well pumps in the City's existing and proposed supply wells to allow those wells to continue to operate. If possible, water levels should also generally be maintained above the tops of the perforated intervals of wells to prevent encrustation, the need for increased maintenance, and premature failure of the well.

3.3. Potential Water Supply Alternatives

Five potential water supply alternatives for the Avondale water system were evaluated using the refined groundwater flow model. The alternatives consider the use of existing wells, constructing the currently planned wells, rehabilitation or redrilling of existing inactive wells, and the development of new wells. It is assumed that new wells well be developed or existing wells will be rehabilitated gradually over time as demand requires with full build-out occurring at the end of planning period in 2050. The alternatives also consider the potential for construction of a surface water treatment plant for the direct treatment of canal water at either near the Avondale Recharge Facility or near 107th Avenue and Roosevelt Road. The effect of a surface water treatment plant is to reduce the need for groundwater to meet future demands.

Avondale is also currently expanding its wastewater treatment facility (Charles M. Wolf Water Resources Center). Whereas the wastewater treatment facility currently discharges reclaimed water to the Aqua Fria River, the expanded facility will redirect the majority of the reclaimed water to the Avondale Recharge Facility. The model simulations account for the influence of increases in infiltrated water from the Avondale Recharge Facility.

3.3.1. Alternative 1

Alternative 1 assumes that the City will continue and expand upon its current strategy of recharging allocated water at the Avondale Recharge Facility and recovering the stored water with groundwater wells. Initial increases in demand will be supplied by bringing the currently planned groundwater wells on-line (Wells 20, 21, 22, 24, 25, 26, 28). Current demand projections suggest that operation of the planned wells will be sufficient to supply demands until the year 2020. Beyond 2020, it assumed that additional demands will first be met by rehabilitating or re-drilling three of the existing groundwater wells that are either currently producing poor water quality or have been deactivated due to historic water quality problems (Wells 1, 8A, and 14). Improved water quality in these wells is anticipated by either redrilling the well or modifying the existing perforated intervals to draw from higher quality depth intervals.

It is assumed that the remainder of additional demand through the end of the planning period will be supplied by new groundwater wells. Assuming that each new well will have a capacity of approximately of 1,200 gpm, it is projected that construction of 11 new groundwater wells will be required by 2050. The locations of potential new wells sites were chosen primarily based on water quality favorability and proximity to the Avondale Recharge Facility, but also on the location of infrastructure, land availability, and a number of other factors. The proposed new well locations are generally spread out across the water favorable water quality area shown of Figure 31. However, all of the new wells are located east of Dysart Road to minimize the potential for drawing contamination from the PGA-North plume. The proposed wells for Alternative 1 are

named according to location and are referred to as wells 30, 31, 32, 33, 34, 35, 36, 39, 40, 45. The well layout at build-out of Alternative 1 is depicted on Figure 32. The timing for bringing wells into operation and the assumed annual pumping rates are summarized in Appendix D.

Alternative 1 also considers the diversion of reclaimed water from the City's wastewater treatment facility to the Avondale Recharge Facility. It is anticipated that the quantity of recharged water at the facility will increase from the 2005 through 2008 average of 7,280 acre-feet/year to 15,000 acre-feet/year. It was assumed that the diversion of reclaimed water would occur in 2010.

3.3.2. Alternative 2

Alternative 2 is similar to Alternative 1 except that two proposed new wells are moved from the north and west of the Avondale Recharge Facility to the south and east of the facility. Proposed new wells 31 and 32 in Alternative 1 are essentially replaced by proposed new wells 38 and 44 with no other modifications to the assumed pumping or recharge conditions. With Alternative 2, no proposed new wells will exist to the north and west of the Agua Fria River where the potential exists for encroachment by the PGA-North contaminant plume. The well layout at build-out of Alternative 2 is depicted on Figure 33 and the assumed annual pumping rates are summarized in Appendix D.

3.3.3. Alternative 3

The proposed new wells in Alternative 3 are arranged to minimize additional distribution system piping to the extent possible, even if the well locations will likely result in the need for additional treatment to address water quality concerns. Alternative 3 is similar to Alternative 2 except three proposed new wells located in the favorable water quality area to the east of the Avondale Recharge Facility (wells 34, 35, 36) are replaced with three new wells located to the southeast of the recharge facility and outside the favorable water quality (referred to as wells 41, 42, and 43). All other pumping and recharge assumptions are the same as Alternative 2. The well layout at build-out of Alternative 3 is depicted on Figure 34 and the assumed annual pumping rates are Appendix D.

3.3.4. Alternatives 4 and 5

Alternatives 4 and 5 assume that a surface water treatment plant will be constructed to directly treat and distribute allocated water. It is assumed that the additional water will come from the Grand Canal and be transported to the plant via a surface lateral. The assumed capacity of the surface water treatment plant upon build-out is 15 mgd, with the initial phase of construction (10 mgd) occurring in 2020 and full build-out occurring in 2030. The year 2020 corresponds to the date when projected demands will exceed the supply from the existing and currently planned groundwater wells. Alternative 4 assumes that the surface water treatment plant will be constructed near the recharge facility, whereas Alternative 5 assumes that the surface water treatment plant will be constructed

near 107th Avenue and Roosevelt Road. The primary difference between the two alternatives is with the configuration of infrastructure.

From the groundwater perspective, Alternatives 4 and 5 are equivalent. The assumed layout of timing of well construction is the same. The primary consequence of constructing a surface water treatment plant is to reduce the need for groundwater within SRP member lands. These lands are entitled to receive water from the Salt River Valley Water Users Association and may be supplied by the surface water treatment plant. Under Alternatives 4 and 5, areas within the SRP member lands will have excess capacity after the surface water treatment plant is constructed. Existing wells within SRP member lands will primarily be used as a backup supply and development of new wells will occur in non-member lands that are not entitled to the surface water.

Alternatives 4 and 5 assume that three wells will be rehabilitated or redrilled and six new wells will be developed on non-member lands following construction of the currently planned wells. The alternatives assume that wells within SRP member lands will be used only as backups with minimal pumping once the surface water treatment plant is brought on-line. The alternatives also assume that the quantity of water recharged at the Avondale Recharge Facility will consist only of water redirected from the City's wastewater treatment facility. This quantity of water is anticipated to be 9,500 acre-feet/year. The well layout at build-out of Alternatives 4 and 5 is depicted on Figure 35 and the assumed annual pumping rates are summarized in Appendix D.

3.4. Future Regional Stress Conditions

Groundwater flow conditions in the Avondale Study Area are largely dependent on the regional stresses being exerted on the basin-fill aquifers in the WSRV. General changes in the highly complex regional distribution of recharge and discharge can result in large changes in groundwater elevations and flow patterns that are unrelated to the proposed modifications to the Avondale water system. For example, a climatic period of above or below normal precipitation or stream flows could cause relatively large increases or decreases in water levels in Study Area regardless of whether additional withdrawals are pursued by the City. Demographic and economic changes such as the conversion of irrigated agricultural land to urban or suburban land uses will certainly occur and will alter the future distribution of pumping and associated drawdowns in groundwater elevations. Other considerations such as the technological and regulatory state-of-affairs are ever evolving and will also affect future groundwater flow conditions.

Since it is not possible to predict with accuracy the changes in the regional stresses that will occur in the future, it is necessary to assume an average stress condition based on both the current and historical magnitude and distribution of stresses for future modeling purposes. Furthermore, since the assumed average conditions are still unlikely to be representative of future regional stresses, this evaluation focuses on predicting the

relative effects caused by modifying the Avondale water system rather than attempting to make concrete absolute predictions of groundwater elevations in the basin. From initial model simulations, it was observed that even modest modifications to assumed regional pumping rates or recharge rates (the largest components of the water budget) resulted in large increases or decreases in water levels in the study (often more than 50 feet). Although model results are provided which show absolute predictions of groundwater elevations (i.e. potentiometric surface maps), these predictions should be applied with caution and within the confines of their intended purpose. The assumptions used to simulate future regional stress conditions are described in the following sections.

3.4.1. Historical Conditions

Future regional stress assumptions were based on the magnitude and distribution of stresses from the historical simulation period of the ADWR model (1983 to 2006). Since 2006 is the most recent date for which data on the stresses in the WSRV is compiled and readily available, the 2006 regional stress conditions were assumed to be representative of current conditions. Simulated regional stresses within the WSRV for the 1983 to 2006 period were obtained from the water budget of the refined model and are summarized on Figure 36.

From Figure 36, it is apparent that 2006 stress conditions in the WSRV were not representative of normal or average conditions in the valley. Most significant was that total pumping from the valley was much less than the average for the 1983 to 2006 time period and that total recharge was greater than the average. Therefore, the 2006 stress conditions could not be assumed for future simulations. Also in apparent from Figure 36 is that the total quantity of recharge to the valley is exhibiting a downward trend over time. This is largely due to decreasing agricultural irrigation returns over time resulting from conversion of cropland to urban and suburban land uses. This decreasing trend is somewhat offset by increases in recharge from artificial recharge facilities. The other major water budget components of stream infiltration and evapotranspiration have been relatively stable over time; however, stream infiltration rates became generally higher after 1992 due to modifications to the Waddell and Roosevelt Dams.

3.4.2. Assumed Future Stress Conditions

Assumed future stresses were assigned by using the current (i.e. 2006) distribution of stresses, but also by applying a multiplier to those stresses to bring the magnitude of the total stress to an average historical condition. Since total pumping from the WSRV has remained approximately steady over time (no long term increases or decreases), a simple average of the 1983 to 2006 pumping rates was assumed for the future condition. Since the average magnitude of pumping (approximately 525,000 acre-feet) is approximately 13% greater than the 2006 magnitude of pumping, a multiplier of 113% was applied to the pumping rates in all wells existing in 2006. This necessarily assumes that spatial distribution of pumping in the valley will remain essentially the same into the future.

A simple average could not be applied to the total recharge because of the declining trend in recharge over time. Instead, a linear trend line was applied to the data and projected to the year 2006. This rate was assumed to be the current average condition (approximately 402,000 acre-feet). The 2006 total recharge rate was approximately 85% of the projected recharge rate. Because of the uncertainty in projecting future trends, it was assumed that total recharge rate would remain steady into the future rather than continuing to decline.

Recharge from artificial recharge facilities is the second largest component of recharge in the WSRV behind agricultural recharge. Since the quantity of artificial recharge has gradually been increasing over time, it was decided to consider this source of recharge separately from the other sources. Future recharge from artificial recharge facilities was assumed to equal in magnitude and distribution to the 2006 artificial recharge (no multiplier was applied). The magnitude of future recharge from the remaining recharge sources was then iteratively adjusted until the total recharge across the model domain was 85% of the 2006 total recharge.

The ADWR model assumed that several components of the total recharge were stable through historical simulation period (canal recharge, lake recharge, urban recharge, etc.). Applying the multiplier to cells containing these sources of recharge reduces the magnitude of recharge contributed from these sources; however, each of these sources is a minor component of the total recharge such that applying the multiplier results in a small overall change.

Stream flows entering the refined model domain varied widely from year to year during the historical simulation period. Years with high stream flows may be separated by several-year-long periods where little or no stream flow occurs. The exceptions are the discharges from the 23rd Avenue and 91st wastewater treatment plants from which relative stable flows originate. Since it is not possible to predict years in which high stream flows will occur versus years with low stream flows, simple average stream flows were assumed at the entry point of each stream into the model domain. Other components of stream definition such as conductance, slope, and width were not changed. This method resulted in simulated future stream infiltration rates that were approximately equivalent to the simulated average from the period from 1992 to 2006, after the modifications to the Waddell and Roosevelt dams.

The time-variable specified head boundaries that simulate inflow and outflow to/from the WSRV subbasin from other subbasins also varied with time during the historical simulation period. The time-variable heads from the end of the 1983 to 2006 simulation period were carried forward into the future. Flows across the boundary were allowed to adjust accordingly. Other model features than those specifically discussed were generally

assumed to be static in the historical simulations and were, therefore, also assumed to be static in the future.

3.5. Model Response

The purpose of assuming an average stress condition for future simulations was to produce a base groundwater flow condition that is similar to current conditions in the Avondale Study Area. A base simulation was run to the end of the 2050 planning period with no modifications to the Avondale Water System to quantify the base flow condition. Inspection of future water level changes in the base simulation showed that both positive and negative water level changes occur in parts of the model domain in future stress periods. This is likely due to real long-term pumping trends, but a part of change is also likely artificial due to short-term pumping rates being greater than or less than normal in portions of the model domain during the 2006 stress period. Since the pumping rates assumed for future stress period were based on the 2006 stress period, short-term increases or decreases in pumping would tend to be carried forward into the future.

Simulated groundwater elevations at several index well locations within the Study Area were chosen to evaluate base condition water level changes in the Study Area through the future stress periods. Simulated hydrographs from these index wells are provided as Figures 37 and 38 (locations shown on Figure 23). Figures 37 and 38 show that base groundwater elevations within the Avondale Study Area remain relatively steady through future time steps. Simulated groundwater elevations at the end of the 2050 planning period are similar to the low-level groundwater elevations exhibited in the year of 2005. Since the water level trends are relatively stable, absolute groundwater elevations simulated by the model for future time steps can be assumed to be approximately representative, but only if it is also assumed that there are no significant changes in regional stresses in the future.

3.6. Simulation Methods

The pumping assigned to the Avondale groundwater wells were annual averages. Actual pumping from the wells is likely to be greater during high demand periods and less during low demand periods. The predicted drawdowns and groundwater elevations from the model should also, therefore, be considered averaged and instantaneous drawdowns may be greater than those predicted. The simulations also do not consider the effects of well inefficiency, which results in greater drawdowns in active pumping wells than in the aquifer immediately surrounding the wells. However, given the long perforated intervals and relatively high aquifer transmissivity, well efficiencies are likely to remain relatively high over time.

The majority of wells in the Avondale water system are constructed with perforated intervals extending across both the UAU and MAU. This resulted in the need to divide

simulated pumping from the wells between layers 1 and 2 in the model. For existing Avondale groundwater wells that were active during the historical simulation period, the proportion of pumping applied to each model layer during the historical period was maintained for future time steps. For planned or proposed new wells, pumping was divided between layers in a manner similar to that employed for ADWR model. A weighting percentage was developed for each well based on the perforated intervals of te well and the simulated hydraulic conductivity values of the model cells. Pumping was divided according to the following equations:

UAU Pumpage = $(K_{UAU} * UAU\%)/(K_{UAU} * UAU\%) + (K_{MAU} * MAU\%)$

MAU Pumpage = $(K_{MAU} * MAU\%)/(K_{MAU} * MAU\%) + (K_{UAU} * UAU\%)$

Where: K_{UAU} = Hydraulic conductivity of the UAU

K_{MAU} = Hydraulic conductivity of the MAU

UAU% = Percentage of perforated interval in UAU

MAU% = Percentage of perforated interval in MAU

For proposed new wells, perforated depth intervals had to be assumed. It was assumed that the bottom of the perforated interval would be at the approximate depth of an extensive clay unit present in the lower MAU (Malcolm Pirnie, 2010). The top of the perforated interval was assumed to be 150 feet below the approximate static water level (estimated from potentiometric surface maps) with a minimum depth of 250 feet bgs. Existing and assumed well details are provided in Table 3-1.

Also provided in Table 3-1 is a list of critical elevations for the existing and proposed new wells. The critical elevation is here defined as the elevation of the top of the highest perforated interval or the elevation of the pump (whichever is shallowest). The critical elevations are pertinent since operational difficulties (i.e. breaking pump suction or encrustation) may be experienced when water levels in the wells drop below the critical elevation. Pump depths for most of the existing wells were unknown. If the well was known to be constructed with a pump gallery, the pump depth was assumed to be in the gallery. If the well was not constructed with a pump gallery or it was unknown whether it was constructed with a pump gallery, the pump depth was assumed to be ten feet above the top of the upper perforated interval.

Table 3-1:
Pump, Perforated Interval, and Critical Elevation Assumptions

Well	Surface Elevation (ft-amsl)	Perforated Intervals (ft-bgs)	Assumed Pump Depth (ft-bgs)	Critical Depth (ft-bgs)	Critical Elevation (ft-amsl)
1	976	244-264,386-398	*265*	244	732
5	934	180-530	*170*	170	764
6	1015	364-604	*354*	354	661
7	1018	320-520	*310*	310	708
8A	1024	289-635	275	275	749
10	997	200-866	*190*	190	807
11	991	100-240	*90*	90	901
12	988	200-867	*190*	190	798
14	980	370-550	*360*	360	620
15	972	370-530	*360*	360	612
16	984	150-190,210-550	195	150	834
16B	983	73-173	*175*	73	910
17	1017	460-670	*450*	450	567
18	994	150-650	*140*	140	854
19	990	150-260	280	150	840
20	1025	299-570,590-800	580	299	726
21	970	340-440,480-560	240	240	730
22	991	300-420,440-560	*430*	300	691
23	1001	148-359	360	148	853
24	1019	440-600	410	410	609
25	972	340-420,440-540	430	340	632
26	977	*250-575*	---	250	727
27	977	*250-550*	---	250	727
28	977	365-430	*355*	355	622
29	976	*250-400*	---	250	726
30	1006	*301-675*	---	301	705
31	985	*259-550*	---	259	726
32	997	*280-675*	---	280	717
33	988	*271-450*	---	271	717
34	990	*255-400*	---	255	735
35	998	*259-400*	---	259	739
36	1012	*271-400*	---	271	741
37	983	*250-500*	---	250	733
38	983	*250-450*	---	250	733
39	982	*250-475*	---	250	732
40	995	*283-550*	---	283	712

Well	Surface Elevation (ft-amsl)	Perforated Intervals (ft-bgs)	Assumed Pump Depth (ft-bgs)	Critical Depth (ft-bgs)	Critical Elevation (ft-amsl)
41	1005	*250-450*	---	250	755
42	995	*250-525*	---	250	745
43	965	*250-525*	---	250	715
44	963	*250-500*	---	250	713
45	1005	*280-400*	---	280	725

*Italics indicate assumed depths.

The Avondale Recharge Facility is simulated in the recharge package. In the ADWR model, recharge from the facility was applied to several grid cells covering a relatively large area with respect to the actual dimensions of the recharge basins. For this evaluation, the recharge was applied to a single refined grid cell that closely approximates the actual dimensions of the basins. Planned future increases in recharged water originating from the Avondale wastewater treatment facility were simulated by simply increasing the simulated rate of recharge to the cell corresponding to the recharge basins.

As discussed above, the evaluation of future water supply alternatives focused on predicting the relative changes to groundwater system caused by the proposed modifications to the Avondale water system. Specifically, the evaluation focused on the drawdowns caused by the future operation of planned, redeveloped, and proposed new wells. To quantify the drawdowns imparted by the proposed changes, a base condition was first simulated which essentially assumed that no additional modifications to the water system would occur. Simulations were then run with the proposed changes and the differences in water levels between the two simulations were used to quantify the distribution of drawdown. Existing wells were assumed to be pumping at an average rate from the period between 2005 and 2009.

Simulated absolute water levels were also evaluated to estimate the effect of the proposed water system changes on groundwater elevations. As discussed above, this necessarily assumes that there are no future modifications to regional stresses and may not be representative. This information is nevertheless useful to evaluate the possible influences of future pumping on the operation of existing wells and to evaluate the possible influence on the movement of contaminant plumes.

3.7. Model Corrections

Due to the relatively large model grid dimensions relative to the actual diameters of the well casings, the relatively steep hydraulic gradients produced near active groundwater wells are not accurately represented by the model. The model produces an average simulated drawdown across the grid cell that is less than the drawdown that would occur

at the actual well head. Groundwater elevations and drawdowns produced at the simulated groundwater wells can be corrected using a form of the Thiem equation (Thiem, 1906).

$$h_w = h_{cell} - \frac{Q}{2\pi T} ln\left(\frac{r_e}{rw}\right) \qquad \text{for confined layers}$$

$$h_w = \sqrt{h_{cell}^2 - \frac{Q}{\pi K} ln \frac{r_e}{r_w}} \qquad \text{for unconfined layers}$$

Where: h_w = water level at the well head

h_c= water level in the grid cell

Q = pumping rate of the well

r_w= radius of the well

r_e = effective well block radius

Since the majority of the Avondale wells are perforated across multiple model layers, groundwater elevations produced in individual layers in the model must composited to account for the effect of each layer. The simulated water level in the well is the weighted average of the water levels from each of layers that well withdraws from as defined by the following equation:

$$h_w = h_{lay1} * p_{lay1} + h_{lay2} * p_{lay2}$$

Where h_{lay1} = water level in layer 1

h_{lay2} = water level in layer 2

p_1 and p_2 are proportions based on the perforated intervals and hydraulic properties of the given layer (assumed to be equal to the proportion of pumping).

The above methods were used estimate the groundwater elevations and drawdowns at each of the existing, planned, and proposed new groundwater wells in the Avondale water system. These elevations and drawdowns were then evaluated to assess the affect on the groundwater system, contaminant plumes, and on the operation of the existing wells. Results from each of the water supply alternatives are discussed in the following sections.

3.8. Simulation Results

Changes in model simulated groundwater elevations caused by the proposed modifications to Avondale Water System are generally controlled by the timing, magnitude, and spatial distribution of additional groundwater withdrawals and by the magnitude of increased recharge at the Avondale Recharge Facility. Drawdowns caused by additional withdrawals are partially offset by increased inflow of water from the recharge facility, and localized increases in groundwater elevations may even occur. Model simulations suggest that groundwater elevations will initially increase after flow from the wastewater treatment facility is routed to recharge facility and prior to when the majority of planned and proposed new wells are brought into operation. As more planned and proposed new wells are brought into operation over time, groundwater elevations gradually decrease. In all six of the alternatives, the maximum simulated drawdowns occurred at full build-out at the end of 2050 planning period. The reported results, therefore, focus on this time period.

3.8.1. Drawdowns

The predicted distribution of drawdown at the end of the 2050 planning period for Alternatives 1 through 5 are depicted on Figures 39 though 42. The figures depict simulated drawdowns from layer 1 of the model (UAU) since drawdowns in this layer are generally greater than those from layers 2 and 3. The layer 1 drawdowns also exhibit the greatest influence from the Avondale Recharge Facility.

The simulated drawdowns from Alternative 1 are depicted on Figure 39. Figure 39 shows up to approximately 17 feet of drawdown from increased withdrawals from the planned wells, proposed new wells, and wells proposed for development at full build-out in 2050. Drawdowns extend across the entire study area with up to 9 feet of drawdown at the eastern edge of the study area, 8 feet of drawdown at the western edge, and 2 feet of drawdown at the southern edge. The depicted drawdowns at the planned, new, and redeveloped well locations are not representative of the predicted drawdowns at the well heads due to the relatively coarse dimensions of the model grid. Based on the Thiem (1906) equation, predicted drawdowns at the wellheads of the planned, new, and redeveloped wells would generally be 5 to 15 greater than those shown on Figure 39.

Figure 39 also shows the effect of groundwater mounding beneath the Avondale Recharge facility. Simulated groundwater elevations rose immediately beneath the recharge facility despite the influences from increased pumping at the planned, proposed new, and redeveloped wells. The magnitude of the rise decreased rapidly with distance from the recharge basins, and was also variable vertically. The degree of mounding decreased greatly in layer 2 and 3, which suggests the finer-grained nature of the MAU restricts the vertical downward movement of recharge water.

The drawdowns from Alternatives 2, and 3 (Figures 40 and 41) are relatively similar to those from Alternative 1. This is because these four alternatives are relatively similar except for relocation of two or three wells in each alternative. Alternative 2 differs from Alternative 1 in that proposed new wells 31 and 32, located to the northwest of the recharge facility, are replaced by proposed new wells 38 and 44, located to the south of the recharge facility. Consequently, the distribution of drawdown predicted for Alternative 2 is shifted slightly to the south relative to Alternative 1. Alternative 3 differs from Alternative 2 in that proposed new wells 34, 35, and 36, located to the east of the recharge facility, are replaced by proposed new wells 41, 42, and 43, located to the southeast of the recharge facility and outside the area of favorable water quality. The distribution of drawdown in Alternative 3 is shifted slightly further to the southeast relative to Alternative 2.

Alternatives 4 and 5 consider the construction of a surface water treatment plant. The primary consequence of a surface water treatment plant is the reduced reliance on groundwater withdrawals, especially within SRP member-lands. These two alternatives also assume that water recharged at the Avondale Recharge Facility will consist only of water redirected from the City's wastewater treatment facility. This results in a decrease in recharge from approximately 15,000 acre-feet/year in Alternatives 1, 2, 3, and 6 to approximately 9,500 acre-feet per year.

The effect of constructing a surface water treatment plant is the reduction of future drawdowns in the aquifer due to decreased need for additional groundwater withdrawals (Figure 42). The model predicts groundwater elevations at the end of the 2050 planning period will be similar current conditions (little to no drawdown) with slight increases around several existing wells that become inactive when the surface water plant is brought on-line. The mounding effect beneath the recharge basins is also predicted to be less due to the decreased quantity of recharged water. In general, the impact to the aquifer will be significantly less for Alternatives 4 and 5 than for Alternatives 1, 2, and 3.

3.8.2. Potentiometric Surface

The potentiometric surfaces (layer 1) predicted for Alternatives 1 through 5 are depicted on Figures 43 though 46. As discussed above, these surfaces assume that little to no change in regional stresses occur into the future. Similar to the predicted drawdowns, the predicted potentiometric surfaces for Alternatives 1, 2, and 3 are very similar to each other. The groundwater flow direction is generally from south to north, but converges near wells 6, 7, and 20. Also apparent is the groundwater mound beneath the Avondale Recharge Facility. The potentiometric surface for Alternatives 4 and 5 are significantly different than those from Alternatives 1, 2, and 3. The general flow direction is slightly more northwestward and there is a less strong convergence towards wells 6, 7, and 20. Groundwater elevations are also higher except in the mound beneath Avondale Recharge Facility where the surface is lower due to the decreased quantity of recharged water.

3.8.3. Mounding

The simulations predict that mounding will occur beneath the recharge basins at the Avondale recharge facility. The predicted increases in groundwater elevations beneath the recharge facility are summarized in Table 3-2. The simulations assume that redirection of water from the Avondale wastewater facility fully occurs in one phase.

The simulations suggest that up to 44 feet of additional increase in groundwater elevations could occur beneath the basins after water is redirected from the wastewater facility. The simulations predict that the degree of mounding will reach a maximum soon after the water is redirected and will then decrease over time as additional wells are brought on-line. The minimum degree of mounding is predicted to occur at the end of the 2050 planning period. The mounding is less for alternatives 4 and 5 than for alternatives 1, 2, and 3 due to the decreased quantity of recharged water.

From Table 8, it is apparent that the mounding effect will be much more subdued in the MAU and LAU than in the UAU. As discussed above, this is due to resistance to vertical flow provided by the finer-grained nature of the MAU. It must be noted that the infiltration of recharge water from the recharge facility is simulated in a general manner such that predictions of the mounding effect are also very generalized. However, if it assumed that the simulations are reasonably approximate, nearly 40 feet of vertical distance will remain between the top of the mound and ground surface under alternatives 1, 2, and 3, and nearly 70 feet will remain under alternatives 4 and 5.

Table 3-2:
Predicted Mounding Effect

Alternative	Predicted Max. Increase (feet)	Predicted 2050 Increase (feet)
Alternative 1		
Layer 1	44.1	28.3
Layer 2	11.8	-6.3
Layer 3	6.9	-9.1
Alternative 2		
Layer 1	44.2	30.1
Layer 2	11.8	-5.7
Layer 3	6.9	-8.9
Alternative 3		
Layer 1	44.2	30.1
Layer 2	11.8	-4.9
Layer 3	6.9	-8.3
Alternatives 4 and 5		
Layer 1	12.9	11.4
Layer 2	3.0	1.9
Layer 3	1.5	1.3

3.8.4. Contaminant Plumes

The influence of Alternatives 1, 2, and 3 on the PGA-North, PGA-South, Western Avenue, and West Van Buren contaminant plumes were relatively similar. The predicted 2050 drawdowns at the contaminant plumes from each of these alternatives were within one to two feet of each other (Table 3-3). The drawdown from each of these alternatives were also relatively small (less than 10 feet) indicating that the proposed additional groundwater withdrawals will have a small influence on the contaminant plumes. The simulations do not include a potential extraction/injection well system that has been proposed for the containment and treatment of the PGA-North contaminant plume. If installed, this system should further minimize the potential impacts to the Avondale groundwater wells. The predicted 2050 potentiometric surfaces for alternatives 1, 2, and 3 suggest the potential for migration of the plumes to the Avondale groundwater wells. The predicted flow direction at the PGA-North plume is to the northeast toward wells 6, 7, 20, and potentially 32. The flow direction beneath PGA-South and Western Avenue plumes ranges from northwest to northeast, but has the potential to migrate towards wells 1 and 14. The mounding effect beneath the Avondale recharge basins provides protection for the wells east of the facility by creating a divide between those wells and PGA-North, PGA-South, and Western Avenue plumes. The flow direction beneath the West Van Buren plume has historically been westward (ADEQ , 2009c) toward the Study Area. The simulations predict that the westward component of flow will decrease over time due to pumping, but this may be an artifact of the assumed future regional stress.

Table 3-3:
Predicted Drawdowns at Contaminant Plumes

Alternative	Predicted Drawdown (feet)			
	PGA-North	PGA-South	Western Ave.	West Van Buren[1]
Alt. 1	7-9	6-8	8	5
Alt. 2	6-8	6-8	8-9	5
Alt. 3	6-8	6-8	8-9	5
Alts. 4 and 5	0-(-2)	0	0	-1

Notes:
(1) Drawdown at western edge of plume.

The predicted drawdown at the contaminant plumes were less for Alternatives 4 and 5 than for Alternatives 1, 2, and 3. The decreased reliance on groundwater for alternatives 4 and 5 results in predicted 2050 groundwater elevations that are similar to current elevations or slightly above. For Alternatives 4 and 5, the groundwater flow direction beneath the PGA-North plume is generally less toward wells 6, 7, and 20, and the groundwater flow direction beneath the PGA-South and Western Avenue plumes is generally less toward wells 1 and 14. The groundwater flow direction beneath the West Van Buren plume was generally similar to Alternatives 1, 2, and 3 due to the larger

distance between this plume and Avondale water system. The simulations predict that Alternatives 4 and 5 will have minimal influences on the contaminant plumes.

3.8.5. Well Operations

The predicted 2050 groundwater elevations were compared to the critical elevations from Table 7 to assess whether future operational difficulties can be expected from the drawdowns imparted by the planned, proposed new, and redeveloped groundwater wells. In general, it was assumed that operational difficulties could occur when simulated groundwater elevations declined below the critical elevation. Simulated groundwater elevations estimated for each of the wells and for each alternative are summarized in Table 3-4.

Predicted groundwater elevations at the wells for Alternatives 1, 2, and 3 were again relatively similar, typically varying by less than four feet for individual wells. Predicted groundwater elevations for Alternatives 4 and 5 were higher due to the lesser reliance on groundwater. Predicted groundwater elevation remained above the critical elevations except for a few wells. The lack of widespread operational difficulties is due to the relatively small drawdowns imparted by the planned, new, and redeveloped groundwater wells and the increase in recharged water from the Avondale Recharge Facility. Predicted groundwater elevations were below the critical elevations for four of the existing groundwater wells. These include wells 11, 16B, 18, and 23.

The predicted groundwater elevations for well 11 were below the critical elevation for all five of the alternatives. Well 11 is a shallow well with a perforated interval from 100 to 240 feet bgs. Due to its shallow perforated interval, current water levels appear to already be below the top of the perforations. Any additional drawdown imparted on this well will unsaturate more of the perforations.

Predicted groundwater elevations for well 16B were also below the critical elevation for all six of the alternatives. Well 16B is an irrigation well, which also has relatively shallow perforations. The perforated interval for well 16B is 73 to 173 feet bgs. Current water levels in this well are also appear to already be below the top of the perforated interval. Any additional drawdown imparted on this well will also unsaturated more of the perforations.

Predicted groundwater elevations for well 18 were just below the critical elevation for Alternatives 1, 2, and 3. However, the predicted groundwater elevations remained just above the critical elevation for Alternatives 4 and 5. Current groundwater elevations are likely just above the top of the perforated interval, and may even be within the perforated interval when pumping. Well 18 has a long perforated interval (extending from 150 to 650 feet bgs), such that desaturating a small upper portion of perforations is not likely to

Table 3-4:
Predicted Groundwater Elevations at Avondale Wells

Well	Critical Elevation (ft-amsl)	Simulated Groundwater Elevation (ft-amsl)				
		Alt.1	Alt. 2	Alt. 3	Alts. 4,5	
1	732	864.6	864.0	863.8	879.2	
5	764	877.5	877.1	876.8	887.3	
6	661	824.3	825.4	826.1	846.8	
7	708	816.1	817.2	817.9	845.5	
8A	749	851.6	854.7	855.2	869.7	
10	807	826.0	827.8	828.7	843.0	
11	901	839.3	840.6	841.4	848.9	
12	798	845.5	846.7	847.8	854.3	
14	620	859.3	859.1	859.1	873.8	
15	612	863.0	862.6	862.4	878.2	
16	834	856.8	857.2	857.9	868.9	
16B	910	871.3	871.6	873.0	879.7	
17	567	846.7	847.1	848.0	861.5	
18	854	842.8	843.2	843.5	855.5	
19	840	848.9	850.0	850.6	861.0	
20	726	801.7	802.8	803.6	834.1	
21	730	871.9	871.4	870.8	891.3	
22	691	863.8	863.5	863.2	881.0	
23	853	817.6	818.1	820.0	870.8	
24	609	856.6	856.7	857.1	873.4	
25	632	860.7	860.3	860.1	876.7	
26	727	877.3	877.0	876.3	892.5	
27	727	857.5	857.7	858.1	871.9	
28	622	862.4	862.2	862.6	873.9	
29	726	---	---	---	---	
30	705	831.4	832.1	832.9	---	
31	726	858.8	---	---	872.2	
32	717	833.3	---	---	---	
33	717	861.4	861.8	871.8	877.2	
34	735	858.6	858.2	---	875.2	
35	739	838.7	838.7	---	---	
36	741	839.9	840.0	---	---	
37	733	865.2	865.4	866.5	877.0	
38	733	---	858.4	859.6	875.6	
39	732	858.7	858.2	858.8	---	
40	712	834.3	835.2	836.3	859.0	
41	755	---	---	860.9	---	
42	745	---	---	867.2	---	
43	715	---	---	865.2	---	
44	713	---	867.1	866.6	---	
45	725	830.4	830.8	832.7	---	

cause serious operational difficulty. It is not known to what depth the pump is installed; however, the pump could be lowered to maintain production, if needed.

Predicted groundwater elevations for well 23 were also below the critical elevation for Alternatives 1, 2, and 3. The pump for well 23 is located in a pump gallery beneath the perforated interval such that breaking pump suction is not a concern. The greatest concern is that the upper portion of the perforated interval will become desaturated. Well 23 is has a relatively shallow perforated interval of 148 to 359 ft bgs. Groundwater elevations could be maintained above the top of the perforations by reducing the pumping rate, if needed. Well 23 was assumed to be inactive for Alternatives 4 and 5, such that predicted groundwater elevations remained above the critical elevation.

On the whole, the additional drawdowns imparted by the proposed water supply alternatives are not likely to cause serious operational difficulties for the Avondale groundwater wells. The predicted groundwater elevations did not exceed the critical elevations for the majority of the wells. Some of the wells with shallow perforated intervals did have exceedences, but these wells likely can be maintained by managing their operation, lowering pumps, or by operating with water levels in the perforated interval, if necessary. Some wells likely already have water levels within the perforated interval and have been successfully operated to date. As discussed above, this evaluation assumes that regional stresses will not change significantly in future. Changes in regional stresses have the potential to significantly affect the operation of the groundwater wells.

3.9. Summary of Results

Predicted future groundwater conditions for water supply Alternatives 1, 2, and 3 were relatively similar indicating that implementing any of these alternatives is likely to have a similar affect on the groundwater flow system. Predicted drawdowns and groundwater elevations were within several feet of each other (except near differing well locations), and the effects on the contaminant plumes were similar. Drawdowns in the aquifer were not excessive, largely due to the offsetting influence of increased recharge water from the Avondale Recharge Facility. The additional drawdowns imparted on the existing groundwater wells may result in some operational difficulties for a few of the existing wells, but these may already be occurring in some of the wells or likely can be remedied with modification of the pump depths, if necessary.

Water supply Alternatives 4 and 5 have less effect on the groundwater system due to the decreased reliance on groundwater withdrawals. These alternatives are likely to result in little long-term change in the groundwater system except for groundwater elevation rises around some deactivated wells and beneath the Avondale recharge basins. The effect on the contaminant plumes and the operation of the existing groundwater wells is also likely to be minimal. Groundwater mounding beneath the recharge facility will be less due the less due to the reduced amount of recharged water.

4. References

ADWR (2009). 1983 to 2006 ADWR Calbirated Spatial Datasets – Version 2. ESRI Geodatabase.

AMEC Earth and Environmental, Inc. (2006). Hydrogeologic Report City of Avondale Production well No. 24, Maricopa County, Arizona. Tempe, Arizona.

AMEC Earth and Environmental, Inc. (2007). Hydrogeologic Report City of Avondale Production Well No. 21, Maricopa County, Arizona. Tempe, Arizona.

Arizona Department of Environmental Quality (2009a). Phoenix Goodyear Airport North EPA NPL Site Estimated Plume Boundary Map. ADEQ GIS and Data Management Unit. Phoenix, Arizona.

Arizona Department of Environmental Quality (2009b). Phoenix Goodyear Airport South EPA NPL Site Estimated Plume Boundary Map. ADEQ GIS and Data Management Unit. Phoenix, Arizona.

Arizona Department of Environmental Quality (2009c). Western Avenue PCE WQARF Site Estimated Plume Boundary Map. ADEQ GIS and Data Management Unit. Phoenix, Arizona.

Arizona Department of Environmental Quality (2009d). West Van Buren WQARF Site Estimated Plume Boundary Map. ADEQ GIS and Data Management Unit. Phoenix, Arizona.

Bota et al. (2004). Salt River Valley Model Calibration Update 1983 – 2002. ADWR Hydrology Division. Memorandum to the Salt River Valley Model File. Phoenix, Arizona.

Clear Creek Associates (2004). Completion Report for Avondale Well 8A. Avondale Arizona. Phoenix, Arizona.

Clear Creek Associates (2006). Completion Report – Avondale Well No. 20, Avondale, Arizona. Scottsdale, Arizona.

Corkhill et al. (1993). A Regional Groundwater Flow Model of the Salt River Valley – Phase 1: Phoenix Active Management Area Hydrogeologic Framework and Basic Date Report. ADWR Hydrology Division Modeling Report No. 6. Phoenix, Arizona.

Corkhill et al. (2006). Salt River Valley Model Geology Update. ADWR Hydrology Division Provision Report. Phoenix, Arizona.

Corell and Corkhill. (1994). A Regional Groundwater Flow Model of the Salt River Valley – Phase 2: Phoenix Active Management Area Numerical Model, Calibration, and Recommendations. ADWR Hydrology Division Modeling Report No. 6. Phoenix, Arizona.

Freihoefer et al. (2009). Regional Groundwater Flow Model of the Salt River Valley: Phoenix Active Management Area Model Update and Calibration. ADWR Hydrology Division Modeling Report No. 6. Phoenix, Arizona.

Harbaugh et al. (2000). MODFLOW-2000, The U.S. Geological Survey Modular Ground-water Model – User Guide to Modularization Concepts and The Gound-water Flow Process. U.S. Geological Survey Open-File Report 00-92.

Malcolm Pirnie (2010). Water Resources Master Plan: Phase 1 – Background Information and Base Data. Phoenix, Arizona.

Thiem, G. (1906). Hydrologische Methoden. Gebhardt, Leipzig.

URS (2003). Final Report Drilling, Installation, and Testing of City of Avondale Rancho Santa Fe Well No. 19. Avondale, Arizona. Phoenix, Arizona.

URS (2005a). Final Report Drilling, Installation, and Testing of City of Avondale Well No. 16, Avondale, Arizona. Phoenix, Arizona.

URS (2005b). Final Drilling, Installation, and Testing of City of Avondale Well No. 23, Avondale, Arizona. Phoenix, Arizona.

N

0 4.5 9 18 27 36 Miles

Legend

- Phoenix Active Management Area
- Phoenix AMA Subbasins
- ADWR Active Model Area

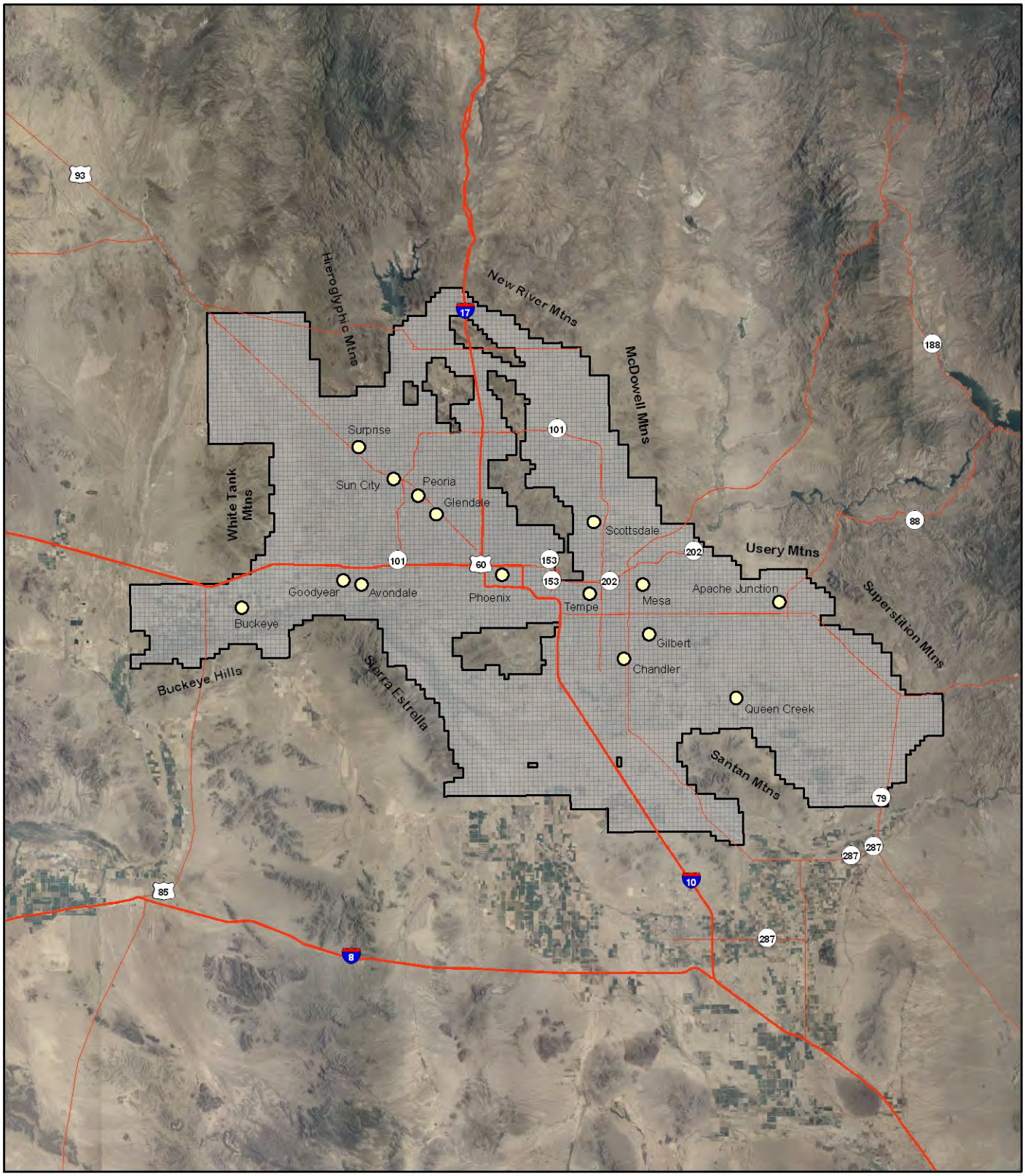
CITY OF AVONDALE, ARIZONA
WATER RESOURCE MASTER PLAN

ADWR MODEL BOUNDARIES

MALCOLM PIRNIE

MAY 2010

FIGURE 1



N

0 7.5 15 22.5 30 Miles

Legend

- City Center
- Major Roads
- ADWR Active Grid Cell

CITY OF AVONDALE, ARIZONA
WATER RESOURCE MASTER PLAN

ADWR MODEL GRID

MALCOLM PIRNIE

MAY 2010

FIGURE 2

Legend

- City Center
- Major Roads
- Section Lines
- ADWR Active Grid Cell

0 7.5 15 22.5 30 Miles

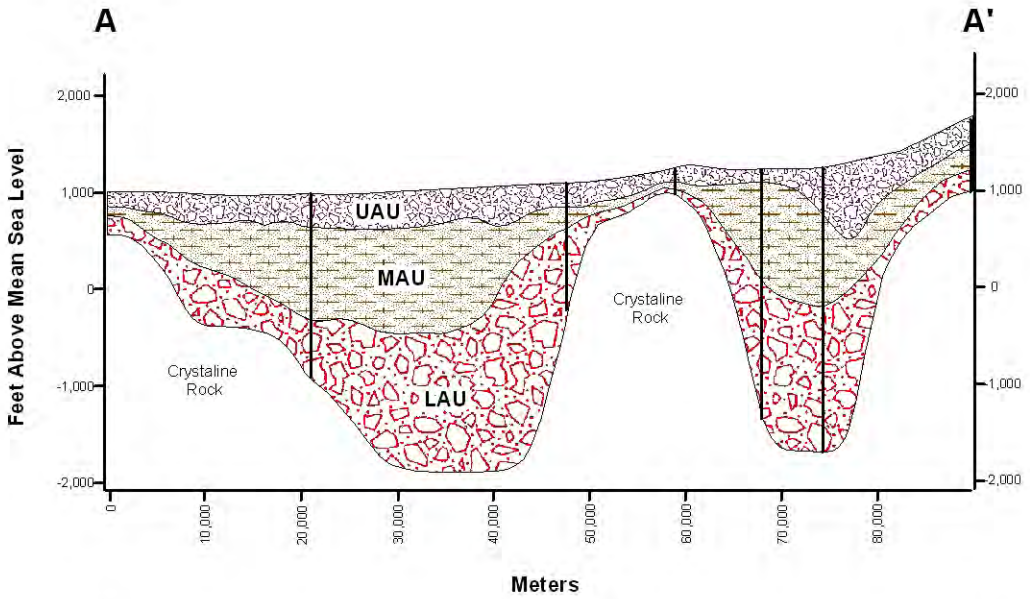
CITY OF AVONDALE, ARIZONA
WATER RESOURCE MASTER PLAN

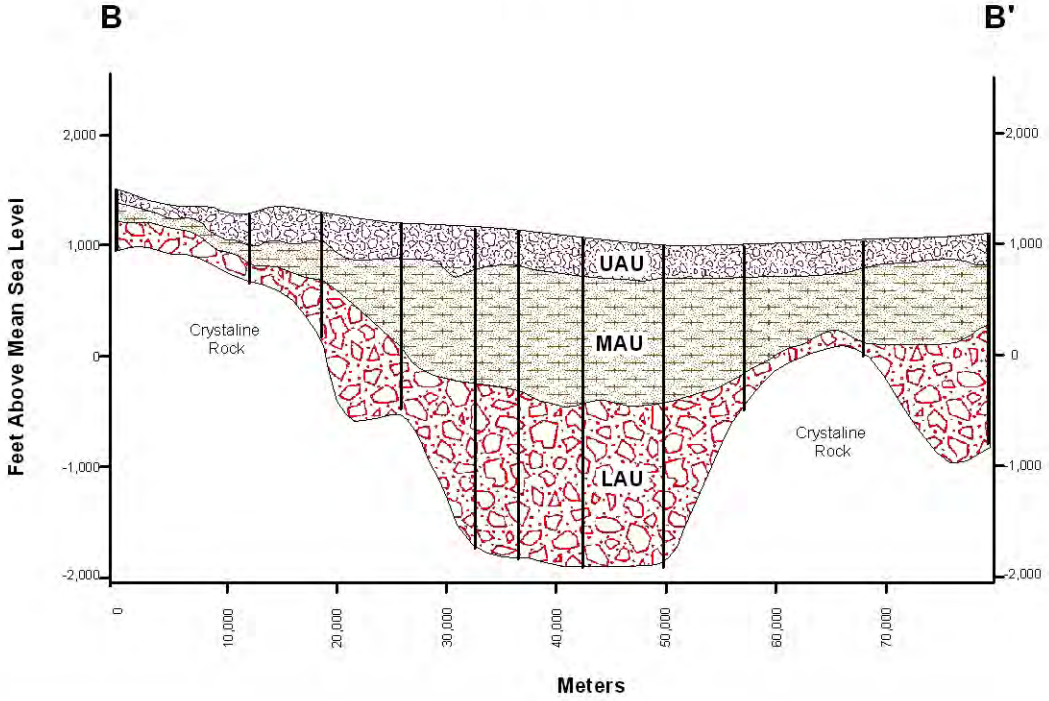
GEOLOGIC CROSS SECTION LOCATIONS

MALCOLM PIRNIE

MAY 2010

FIGURE 3





Legend

- Geologic Data Point
- UAU
- MAU
- LAU

Scale: As Noted

Figure adapted from Freihoefer et al. (2009)

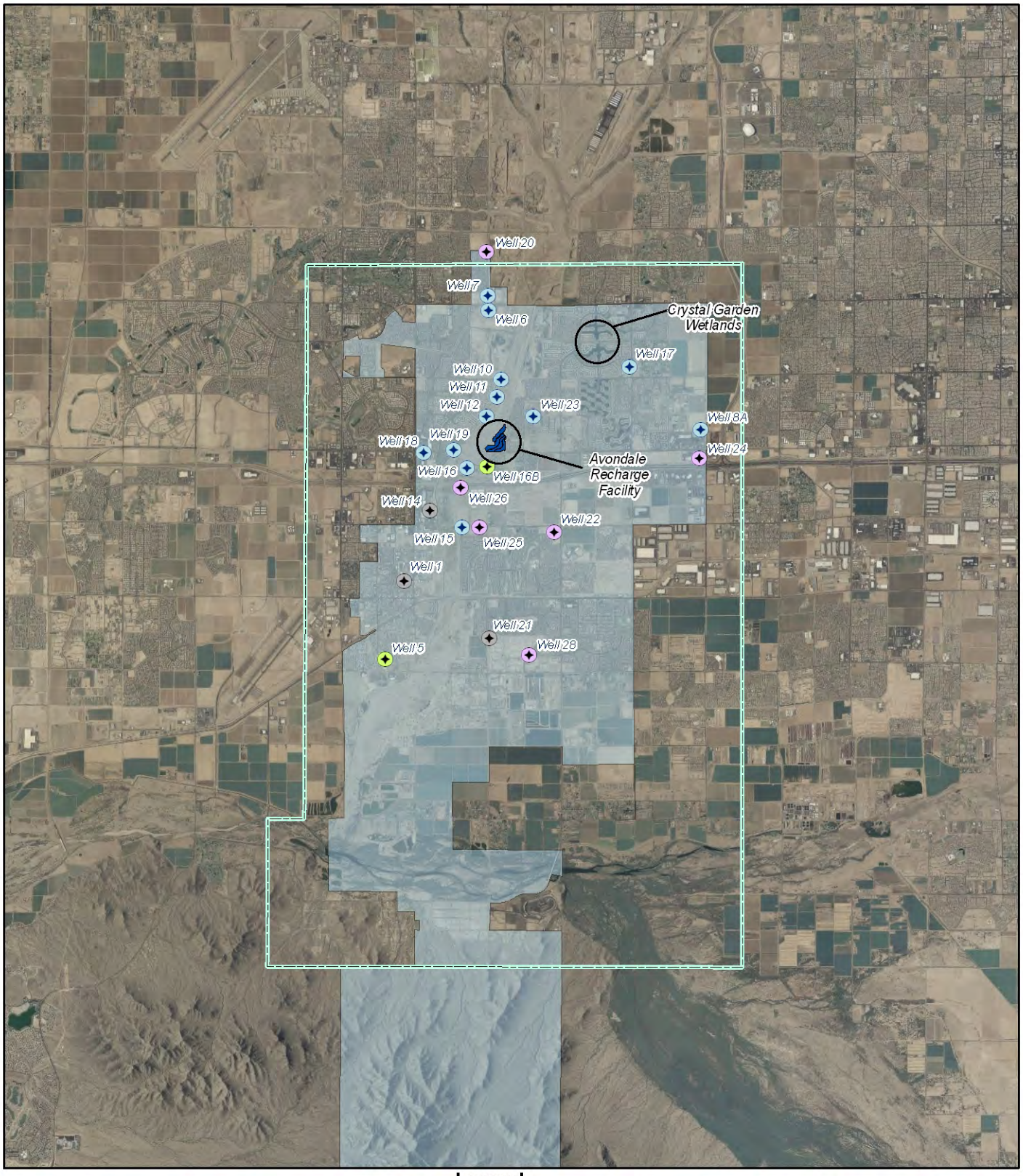
CITY OF AVONDALE, ARIZONA
WATER RESOURCE MASTER PLAN

GENERALIZED GEOLOGIC CROSS SECTIONS

MALCOLM PIRNIE

MAY 2010

FIGURE 4



Legend

- Active Well
- Inactive Well
- Irrigation Well
- Planned Well
- Avondale Water Service Area
- Avondale Study Area
- Model Grid Cell

0 5,000 10,000 15,000 20,000 Feet

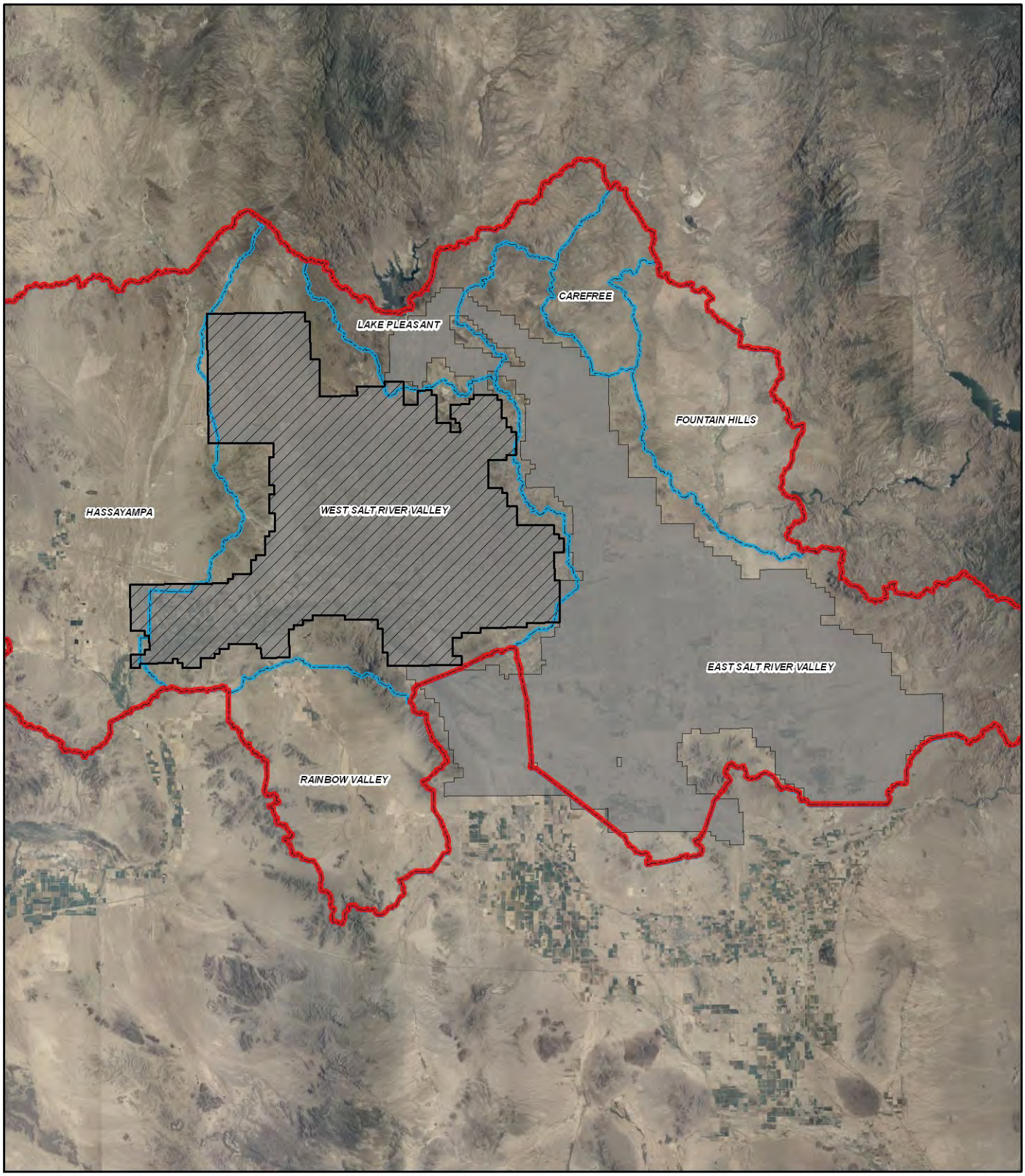
CITY OF AVONDALE, ARIZONA
WATER RESOURCE MASTER PLAN

AVONDALE WATER SYSTEM

MALCOLM PIRNIE

MAY 2010

FIGURE 5



N

0 7.5 15 22.5 30 Miles

Legend

- Phoenix AMA Subbasins
- Refined Active Model Area
- ADWR Active Model Area

City of Avondale

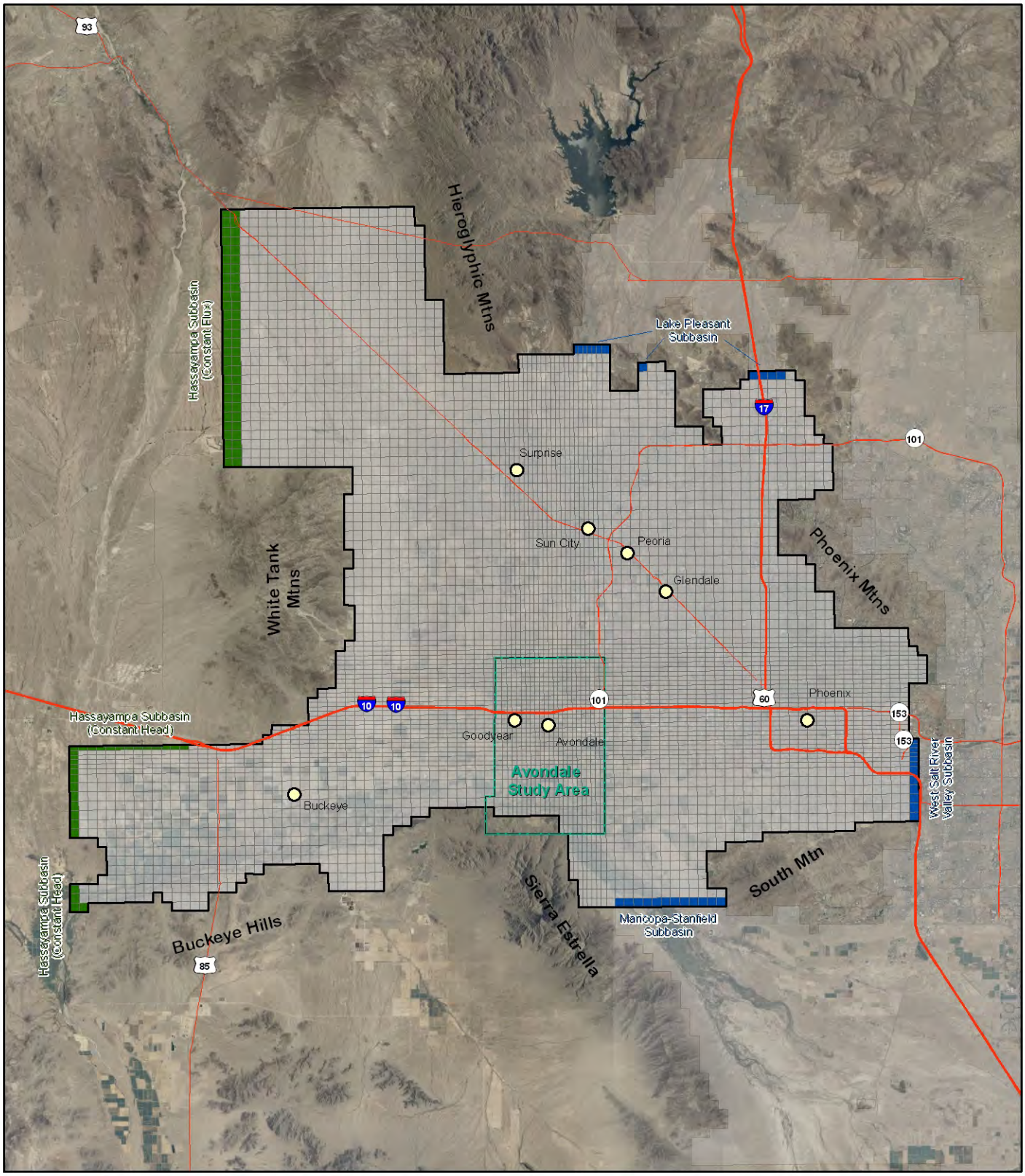
CITY OF AVONDALE, ARIZONA
WATER RESOURCE MASTER PLAN

REFINED MODEL BOUNDARIES

MALCOLM PIRNIE

MAY 2010

FIGURE 6



N

0 20,000 40,000 60,000 80,000 Feet

Legend

- City Center
- Major Roads
- Avondale Study Area
- Refined Model Active Grid Cell
- ADWR Active Model Area
- New Model Boundaries
- Existing Model Boundaries

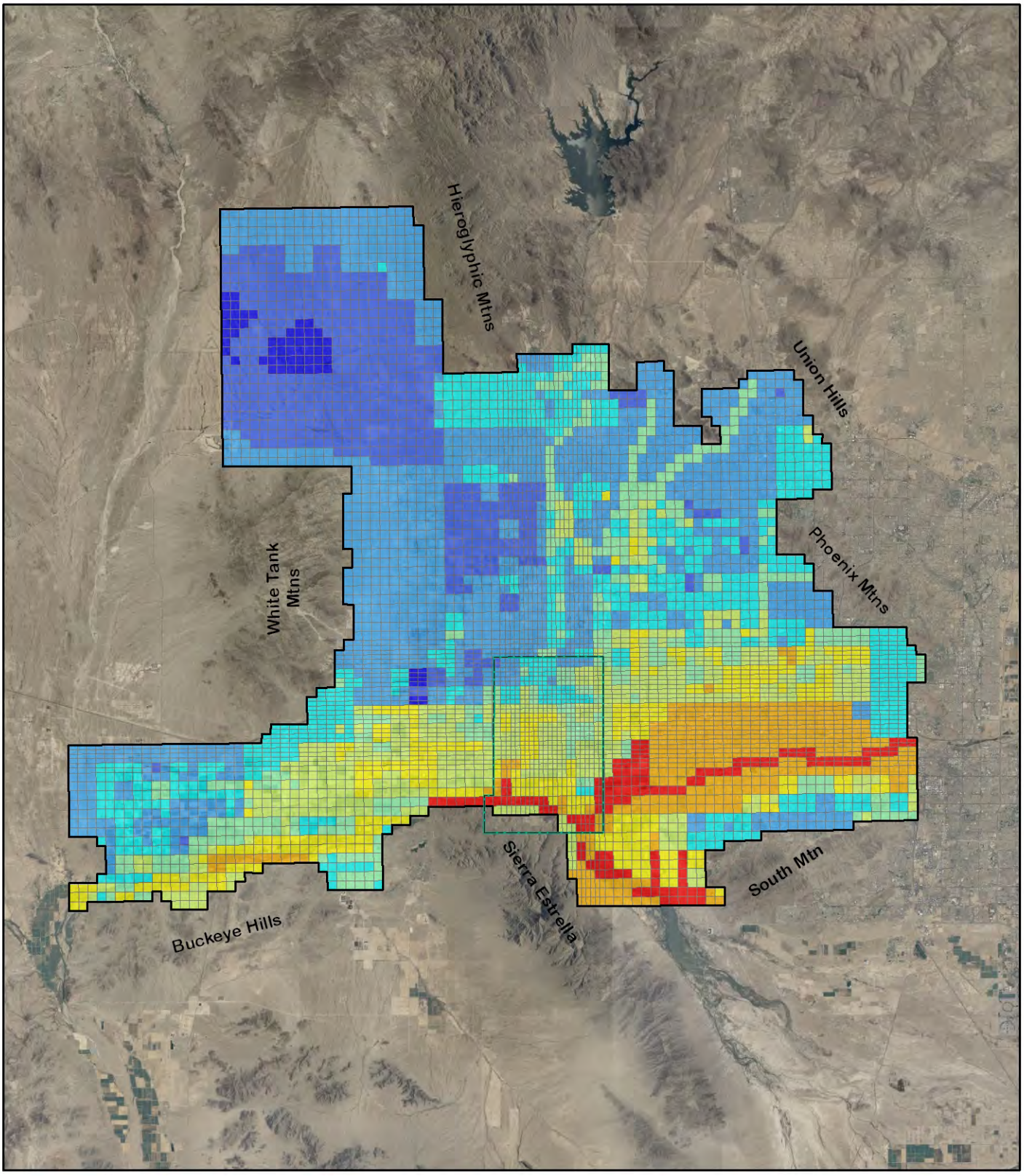
CITY OF AVONDALE, ARIZONA
WATER RESOURCE MASTER PLAN

REFINED MODEL GRID

MALCOLM PIRNIE

MAY 2010

FIGURE 7



N

0 20,000 40,000 60,000 80,000 Feet

Legend

Avondale Study Area

Hydraulic Conductivity (feet/day)

- 1 - 5
- 5.1 - 10
- 10.1 - 20
- 20.1 - 30
- 30.1 - 40
- 40.1 - 50
- 50.1 - 75
- 75.1 - 100
- 100.1 - 150
- 150.1 - 200

City of Avondale

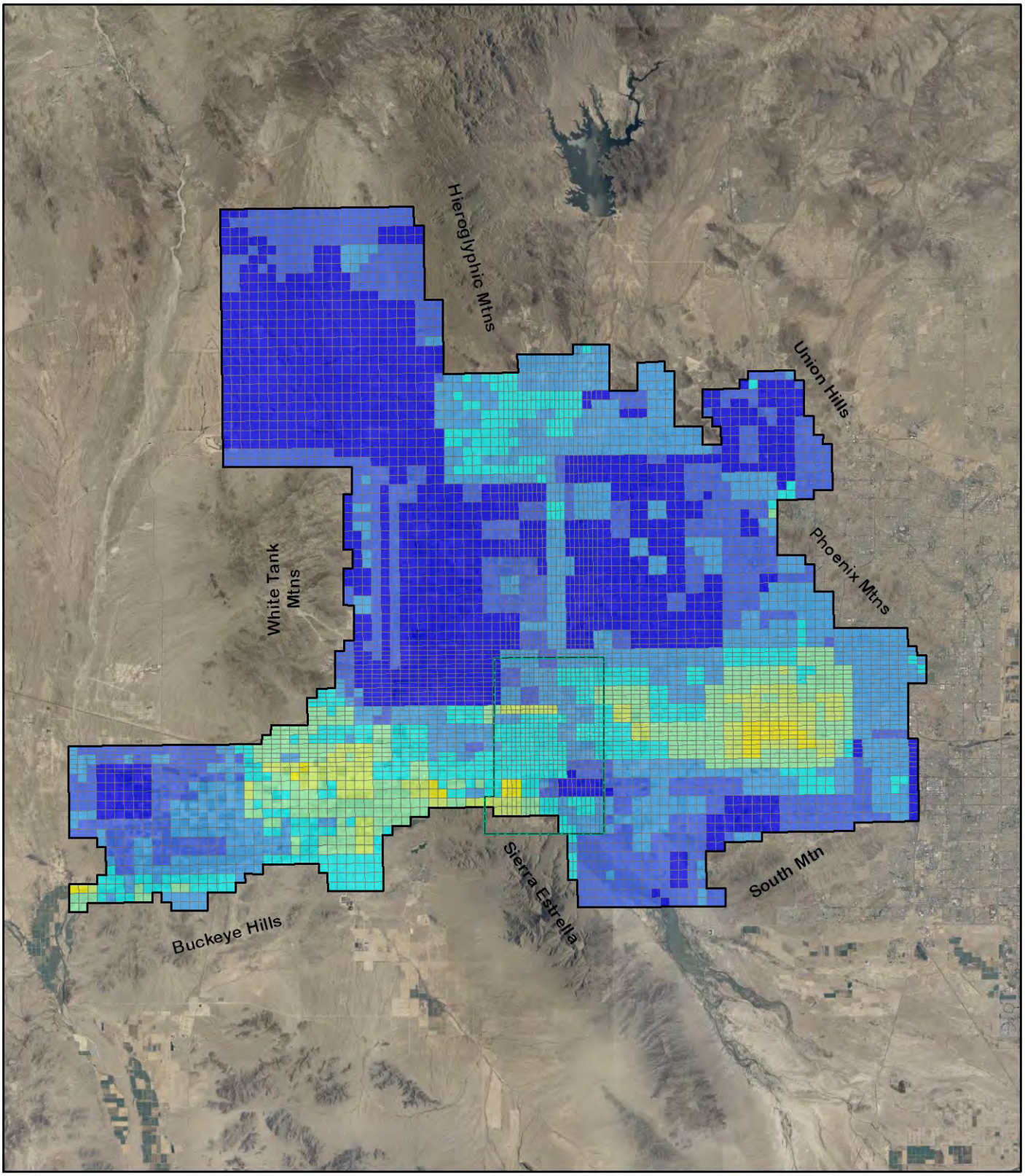
CITY OF AVONDALE, ARIZONA
WATER RESOURCE MASTER PLAN

HYDRAULIC CONDUCTIVITY - LAYER ONE

MALCOLM PIRNIE

MAY 2010

FIGURE 8



N

0 20,000 40,000 60,000 80,000 Feet

Legend

Avondale Study Area

Hydraulic Conductivity (feet/day)

- 1 - 5
- 5.1 - 10
- 10.1 - 20
- 20.1 - 30
- 30.1 - 40
- 40.1 - 50
- 50.1 - 75
- 75.1 - 100
- 100.1 - 150
- 150.1 - 200

City of Avondale

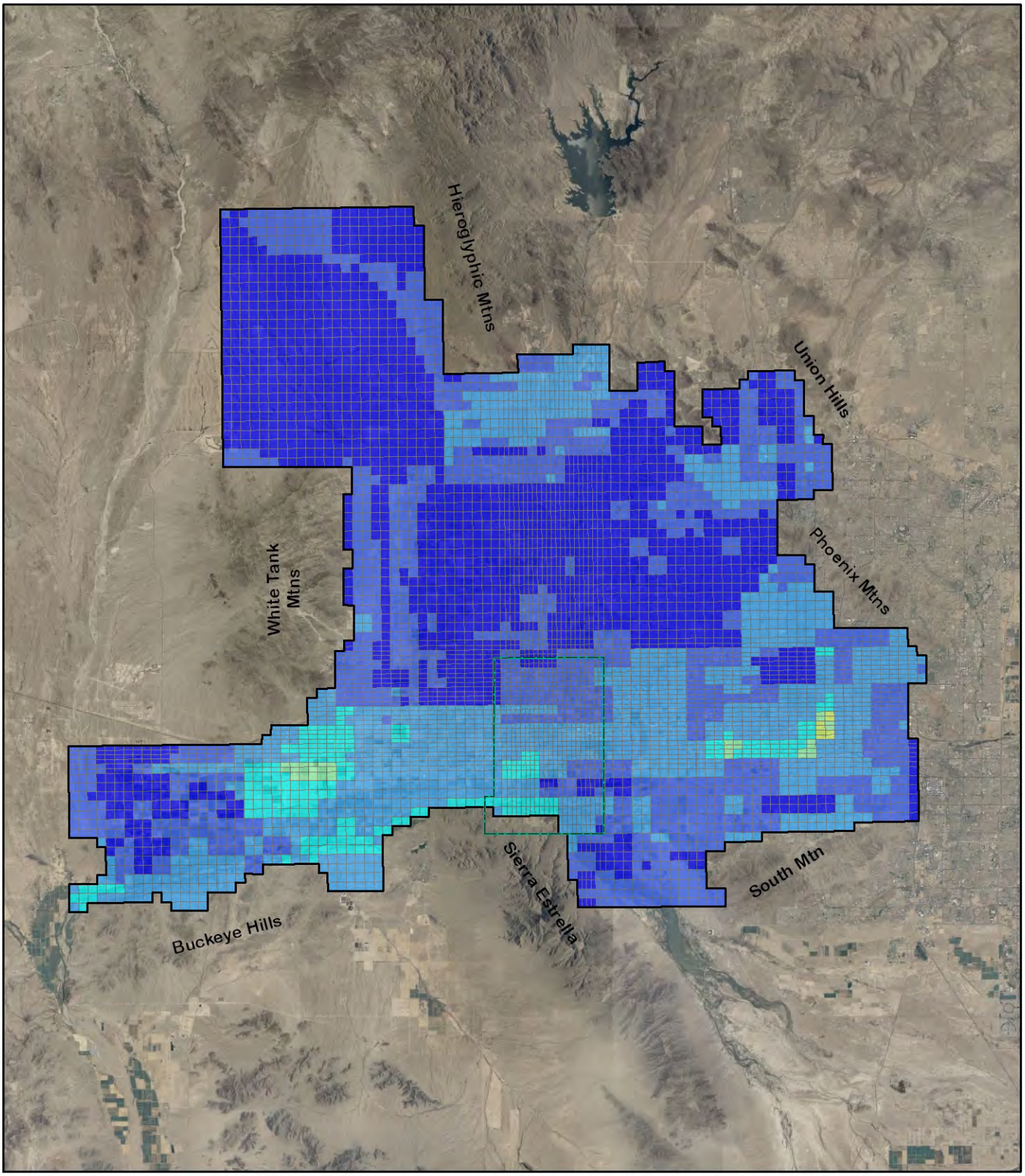
CITY OF AVONDALE, ARIZONA
WATER RESOURCE MASTER PLAN

HYDRAULIC CONDUCTIVITY - LAYER TWO

MALCOLM PIRNIE

MAY 2010

FIGURE 9



N

0 20,000 40,000 60,000 80,000 Feet

Legend

Avondale Study Area

Hydraulic Conductivity (feet/day)

- 1 - 5
- 5.1 - 10
- 10.1 - 20
- 20.1 - 30
- 30.1 - 40
- 40.1 - 50
- 50.1 - 75
- 75.1 - 100
- 100.1 - 150
- 150.1 - 200

City of Avondale

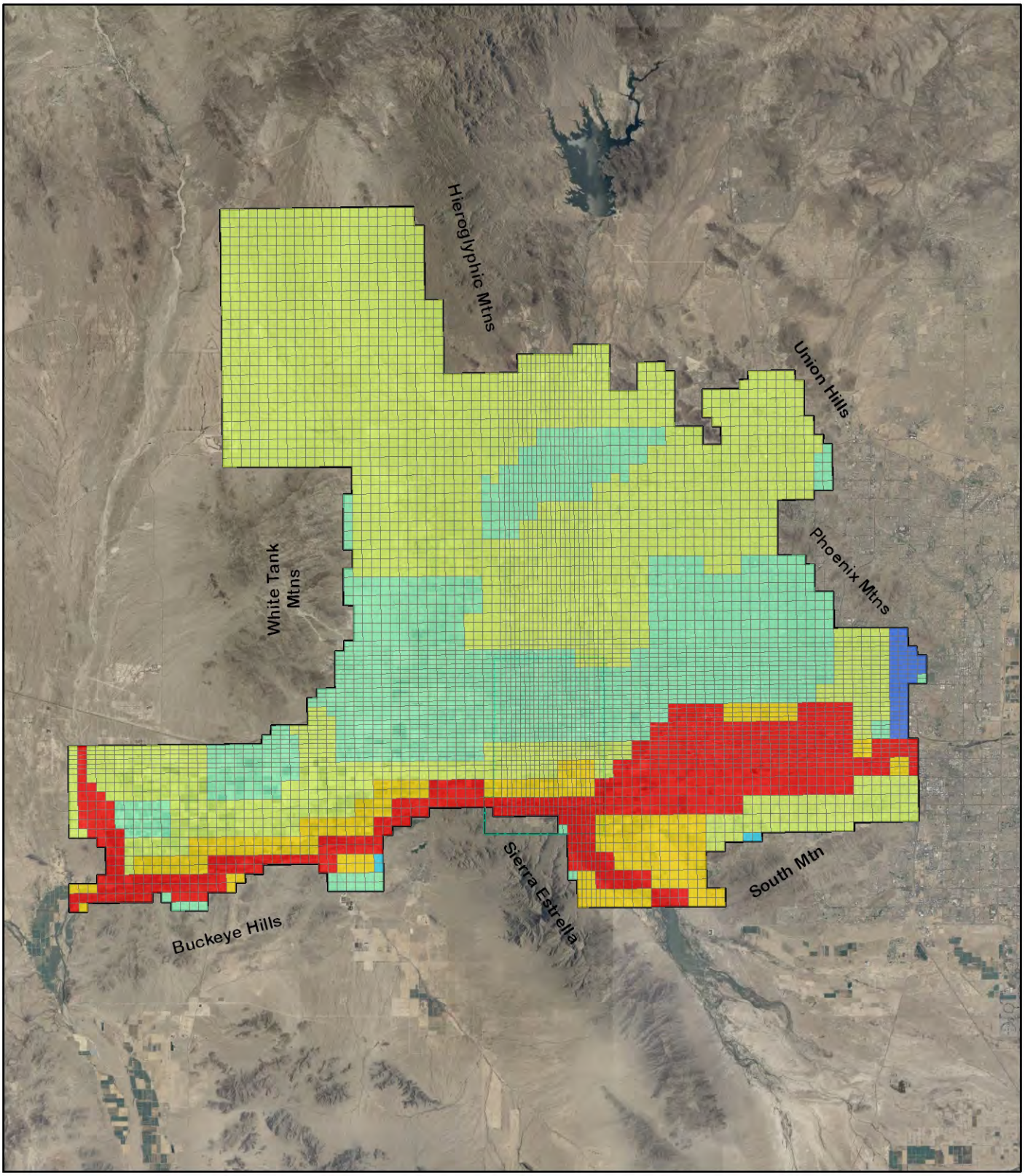
CITY OF AVONDALE, ARIZONA
WATER RESOURCE MASTER PLAN

HYDRAULIC CONDUCTIVITY - LAYER THREE

MALCOLM PIRNIE

MAY 2010

FIGURE 10



N

0 20,000 40,000 60,000 80,000 Feet

Legend

Avondale Study Area

Specific Yield (percent)

- 1 - 3
- 3.1 - 5
- 5.1 - 7
- 7.1 - 9
- 9.1 - 12
- 12.1 - 16
- 16.1 - 18
- 18.1 - 20

City of Avondale

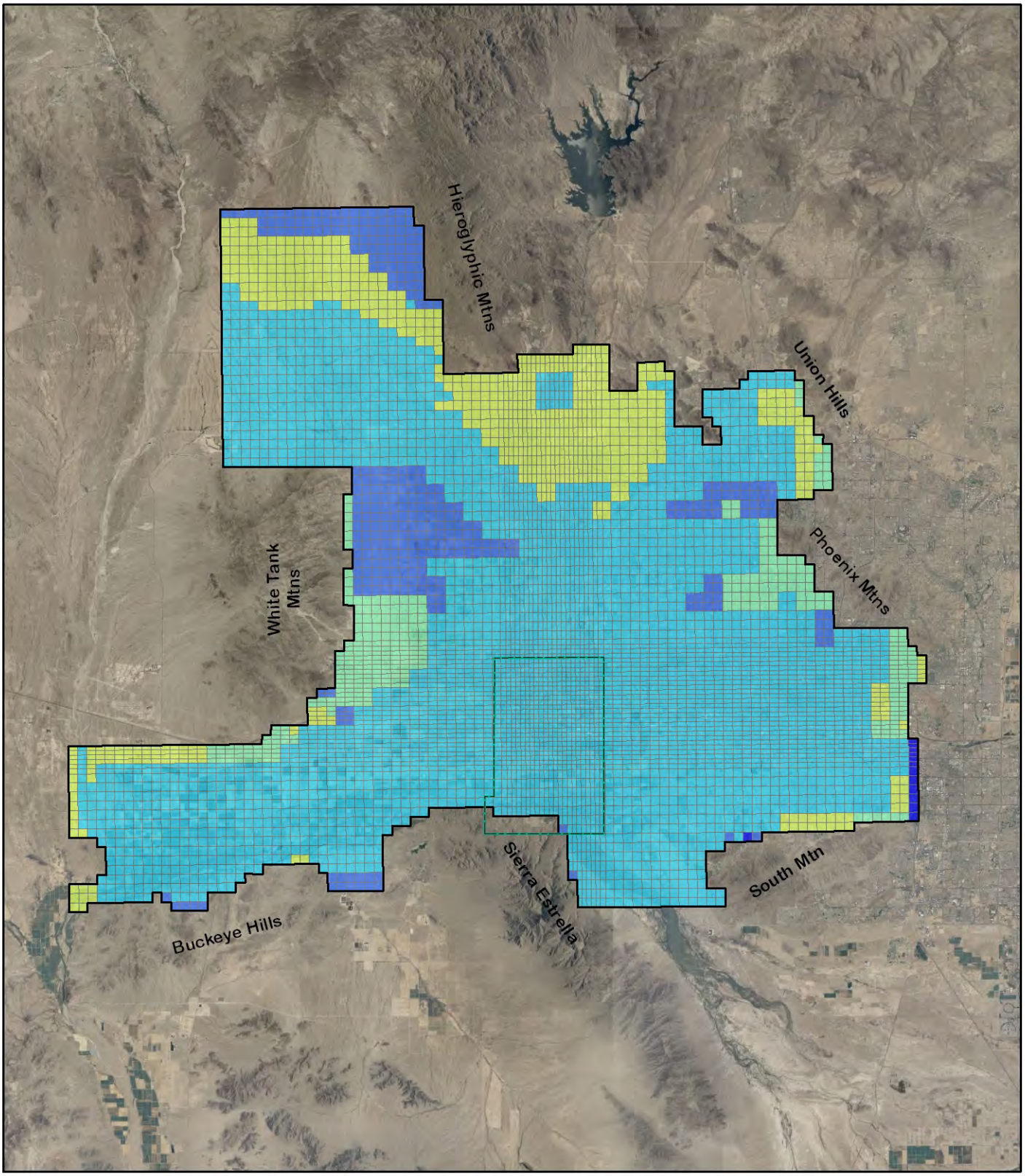
CITY OF AVONDALE, ARIZONA
WATER RESOURCE MASTER PLAN

SPECIFIC YIELD - LAYER ONE

MALCOLM PIRNIE

MAY 2010

FIGURE 11



N

0 20,000 40,000 60,000 80,000 Feet

Legend

Avondale Study Area

Specific Yield (percent)

- 1 - 3
- 3.1 - 5
- 5.1 - 7
- 7.1 - 9
- 9.1 - 12
- 12.1 - 16
- 16.1 - 18
- 18.1 - 20

City of Avondale

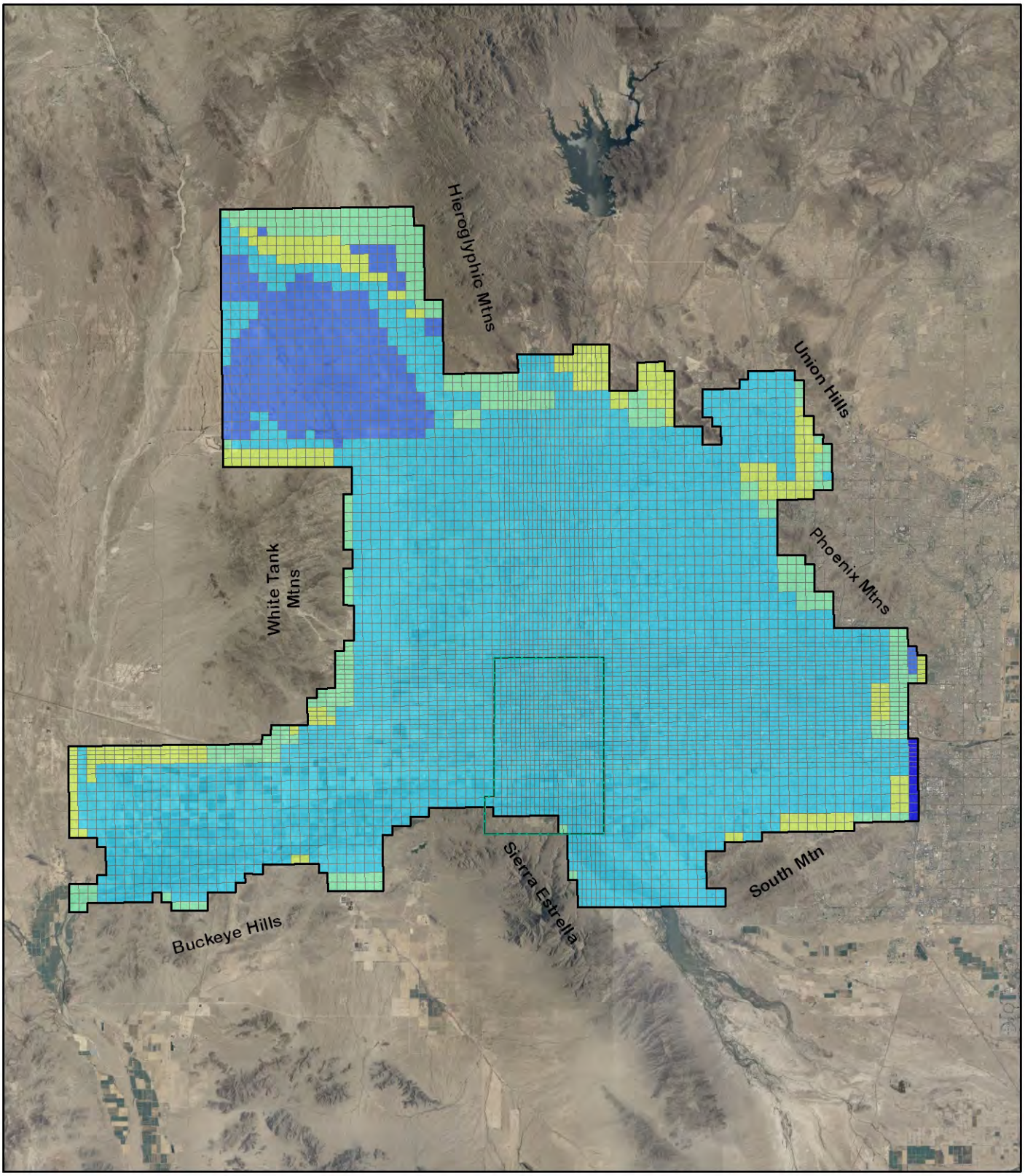
CITY OF AVONDALE, ARIZONA
WATER RESOURCE MASTER PLAN

SPECIFIC YIELD - LAYER TWO

MALCOLM PIRNIE

MAY 2010

FIGURE 12



N

0 20,000 40,000 60,000 80,000 Feet

Legend

Avondale Study Area

Specific Yield (percent)

1 - 3	9.1 - 12
3.1 - 5	12.1 - 16
5.1 - 7	16.1 - 18
7.1 - 9	18.1 - 20

City of Avondale

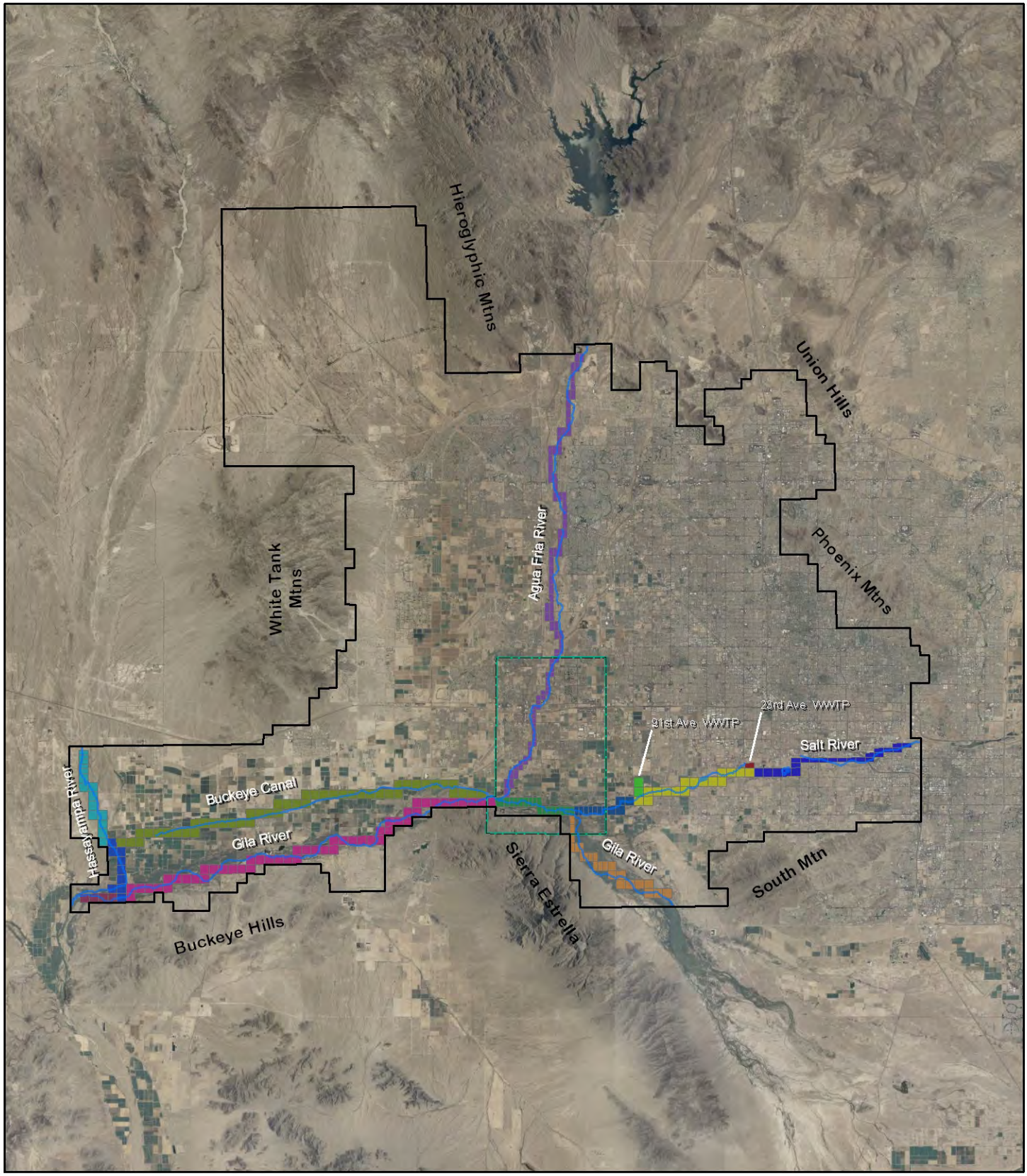
CITY OF AVONDALE, ARIZONA
WATER RESOURCE MASTER PLAN

SPECIFIC YIELD - LAYER THREE

MALCOLM PIRNIE

MAY 2010

FIGURE 13



N

0 20,000 40,000 60,000 80,000 Feet

Legend

Avondale Study Area

Major Stream

Stream Segment

1 2 3 4 5 6 7 8 9 10 11 12 13 14

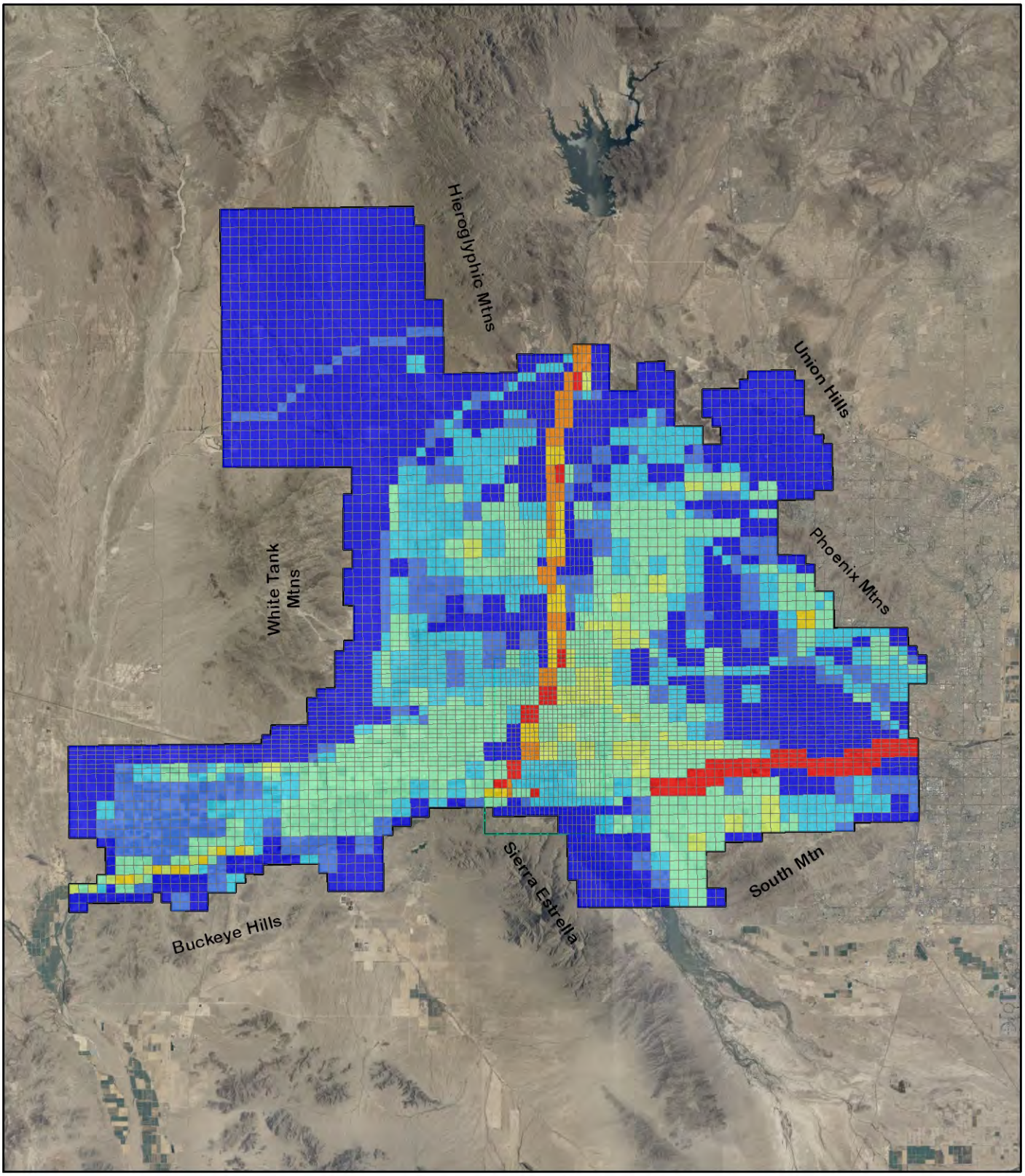
CITY OF AVONDALE, ARIZONA
WATER RESOURCE MASTER PLAN

STREAMS

MALCOLM PIRNIE

MAY 2010

FIGURE 14



Legend

Avondale Study Area

0 20,000 40,000 60,000 80,000 Feet

Total Recharge Rate (Acre-feet/Year/Cell)

Note: total recharge = combined mountain front, stream infiltration, agricultural, canal, lake, urban, turf, and artificial recharge

1 - 50	401 - 600
51 - 100	601 - 800
101 - 200	801 - 1,000
201 - 400	> 1,000

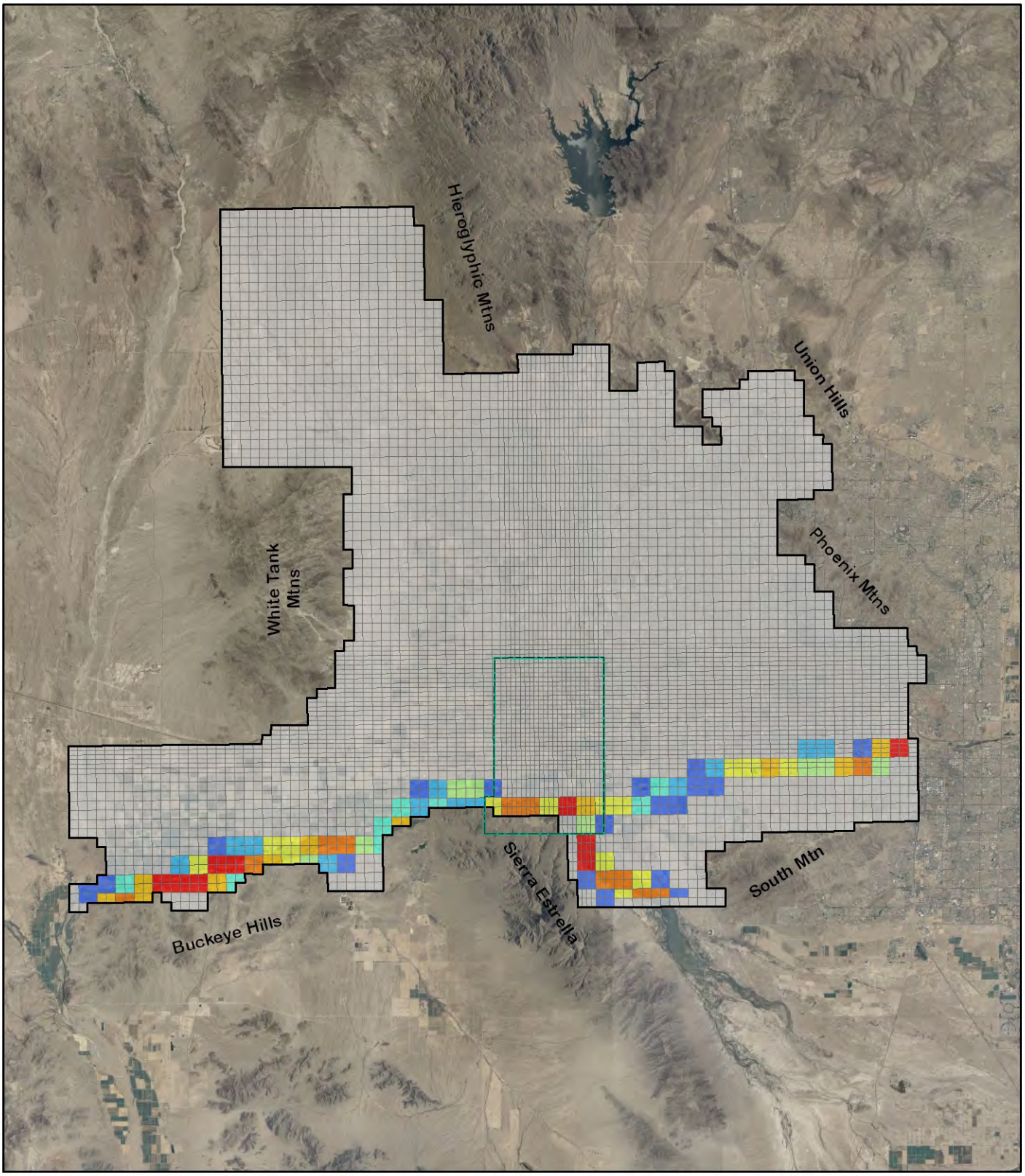
CITY OF AVONDALE, ARIZONA
WATER RESOURCE MASTER PLAN

2006 TOTAL RECHARGE

MALCOLM PIRNIE

MAY 2010

FIGURE 15



N

0 20,000 40,000 60,000 80,000 Feet

Legend

Avondale Study Area

Evapotranspiration Rate (Acre-feet/Year/Cell)

Note: Extinction depth = 30 feet

0			
1 - 50		201 - 300	
51 - 100		301 - 400	
101 - 150		401 - 500	
151 - 200		501 - 800	

City of Avondale

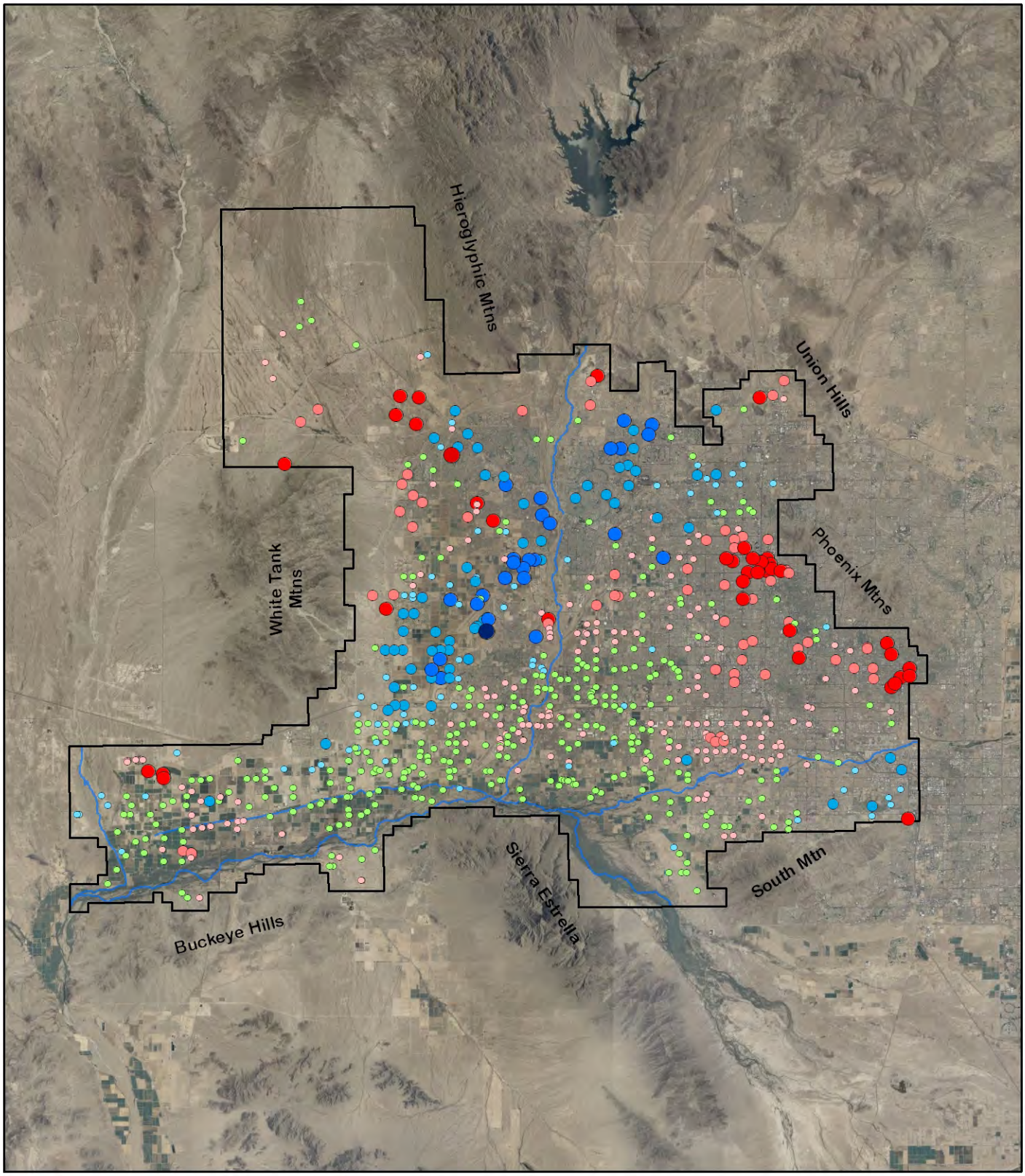
CITY OF AVONDALE, ARIZONA
WATER RESOURCE MASTER PLAN

EVAPOTRANSPIRATION RATE

MALCOLM PIRNIE

MAY 2010

FIGURE 16



Residual Error (feet)

Under Simulated	Over Simulated
> (-100)	0 - 10
(-99.9) - (-50)	10.1 - 25
(-49.9) - (-25)	25.1 - 50
(-24.9) - (-10)	50.1 - 100
(-9.9) - 0	>100

Legend

Avondale Study Area

Major Stream

N

0 20,000 40,000 60,000 80,000 Feet

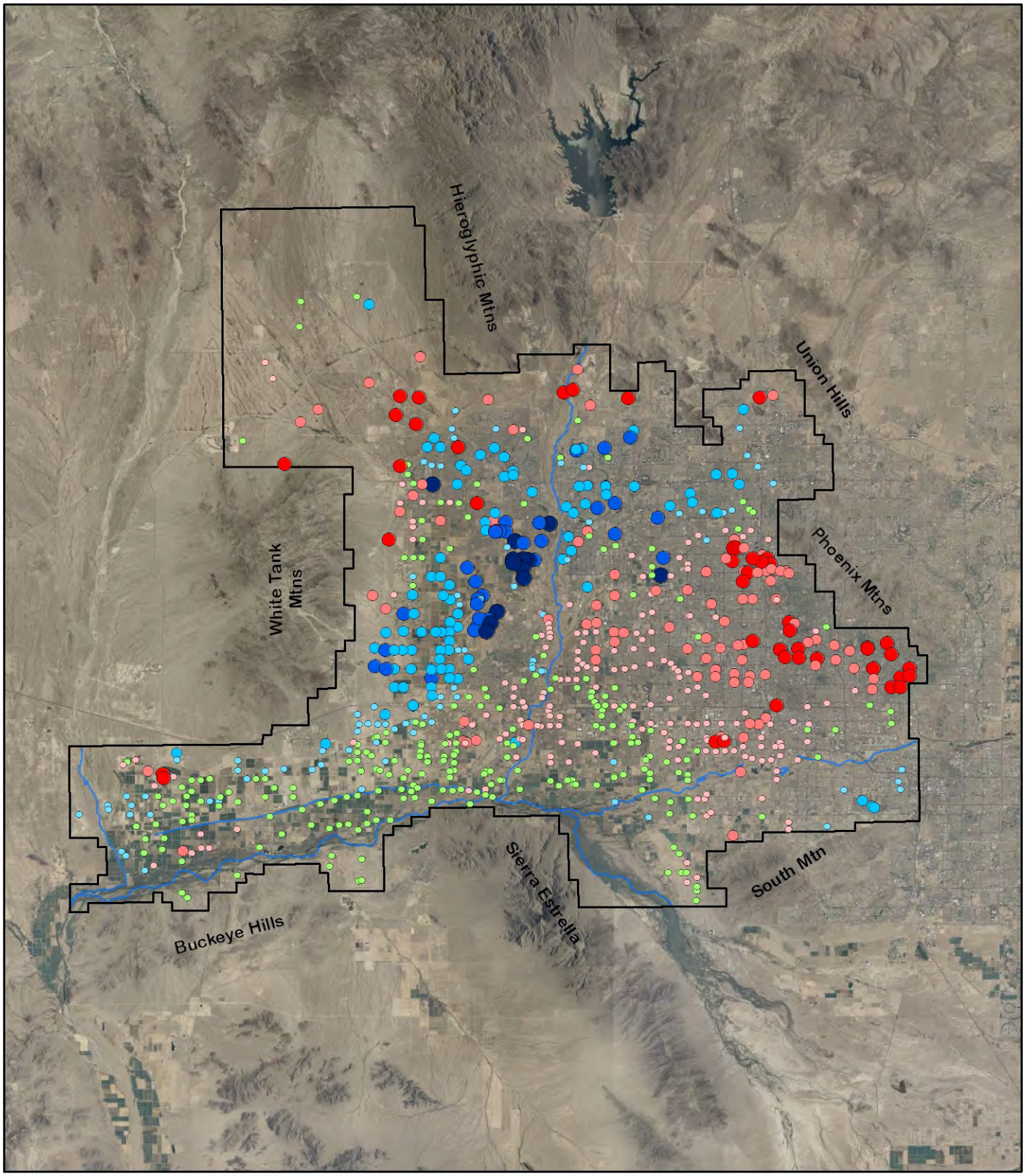
City of Avondale

CITY OF AVONDALE, ARIZONA
WATER RESOURCE MASTER PLAN
MODEL ERROR
WINTER 1991/1992 WATER LEVEL SWEEP

MALCOLM PIRNIE

MAY 2010

FIGURE 17



N

0 20,000 40,000 60,000 80,000 Feet

Legend

Avondale Study Area

Major Stream

Residual Error (feet)

Under Simulated	Over Simulated
> (-100)	0 - 10
(-99.9) - (-50)	10.1 - 25
(-49.9) - (-25)	25.1 - 50
(-24.9) - (-10)	50.1 - 100
(-9.9) - 0	>100

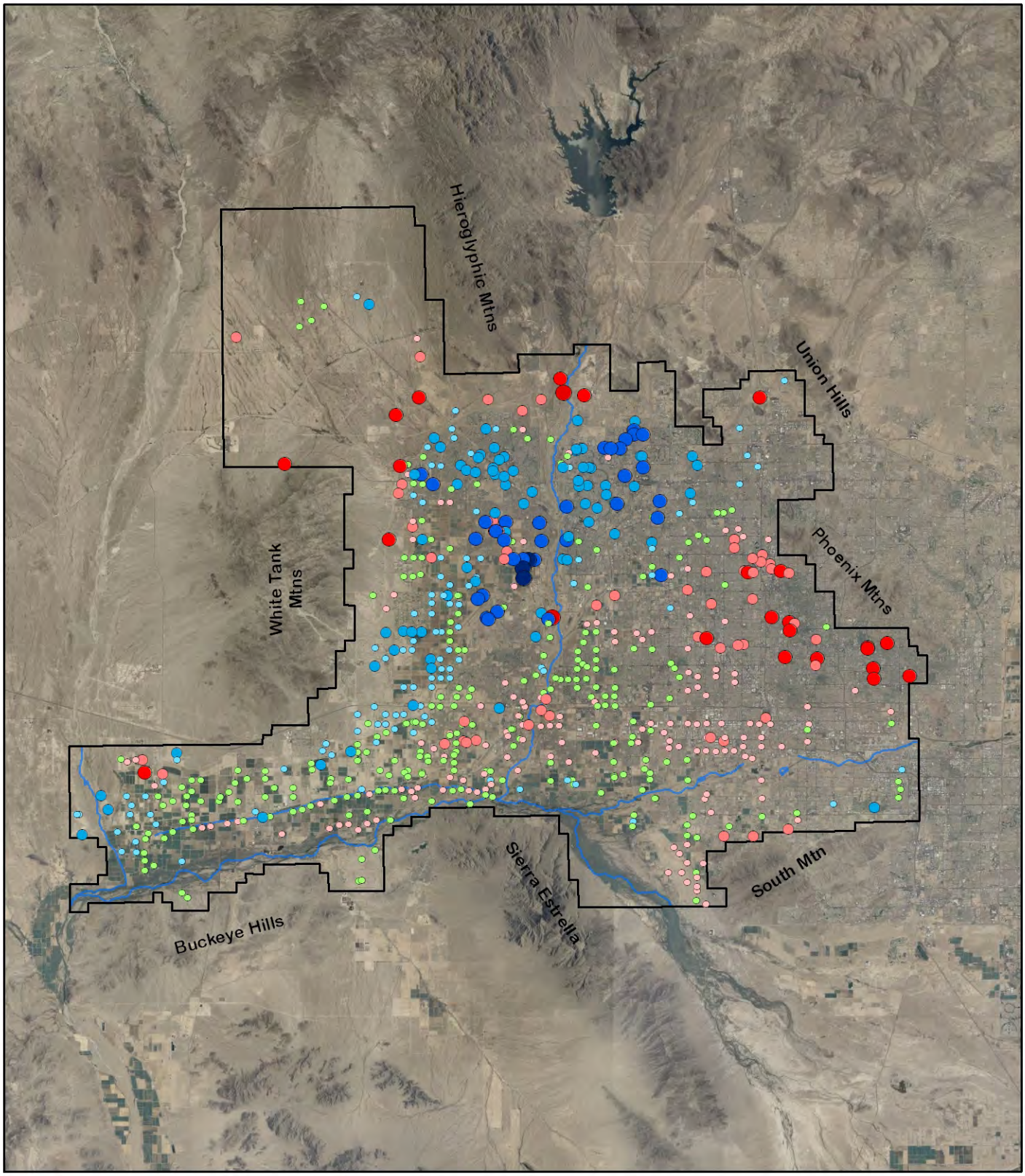
City of Avondale

CITY OF AVONDALE, ARIZONA
WATER RESOURCE MASTER PLAN
MODEL ERROR
WINTER 1997/1998 WATER LEVEL SWEEP

MALCOLM PIRNIE

MAY 2010

FIGURE 18



Residual Error (feet)

Under Simulated	Over Simulated
> (-100)	0 - 10
(-99.9) - (-50)	10.1 - 25
(-49.9) - (-25)	25.1 - 50
(-24.9) - (-10)	50.1 - 100
(-9.9) - 0	>100

Legend

Avondale Study Area

Major Stream

N

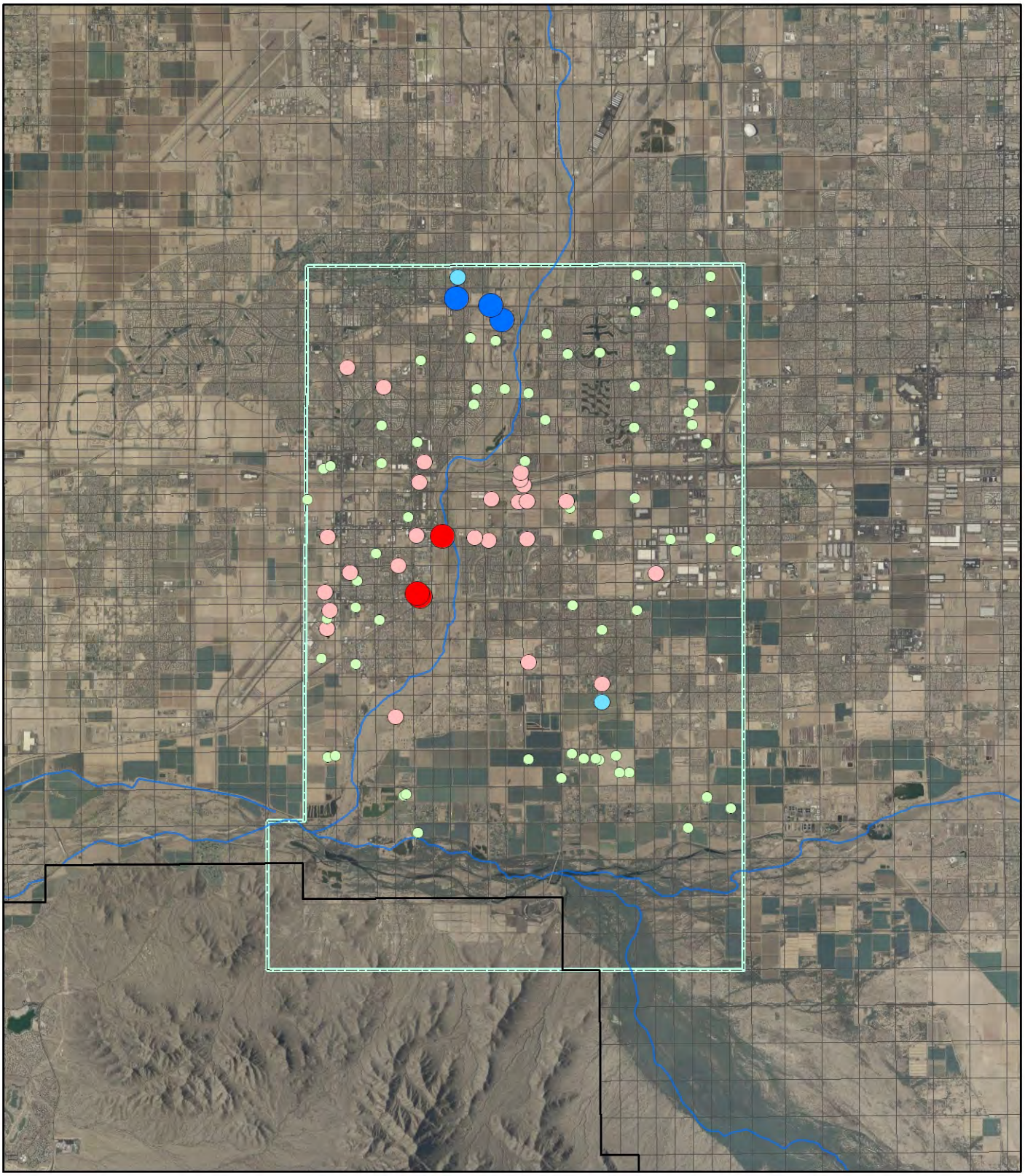
0 20,000 40,000 60,000 80,000 Feet

CITY OF AVONDALE, ARIZONA
WATER RESOURCE MASTER PLAN
MODEL ERROR
WINTER 2002/2003 WATER LEVEL SWEEP

MALCOLM PIRNIE

MAY 2010

FIGURE 19



N

0 5,000 10,000 15,000 20,000 Feet

Legend

Major Stream

Avondale Study Area

Model Grid Cell

Residual Error (feet)

Under Simulated

> (-20)

(-20) - (-10)

(-10) - 0

0 - 10

10 - 20

Over Simulated

> 20

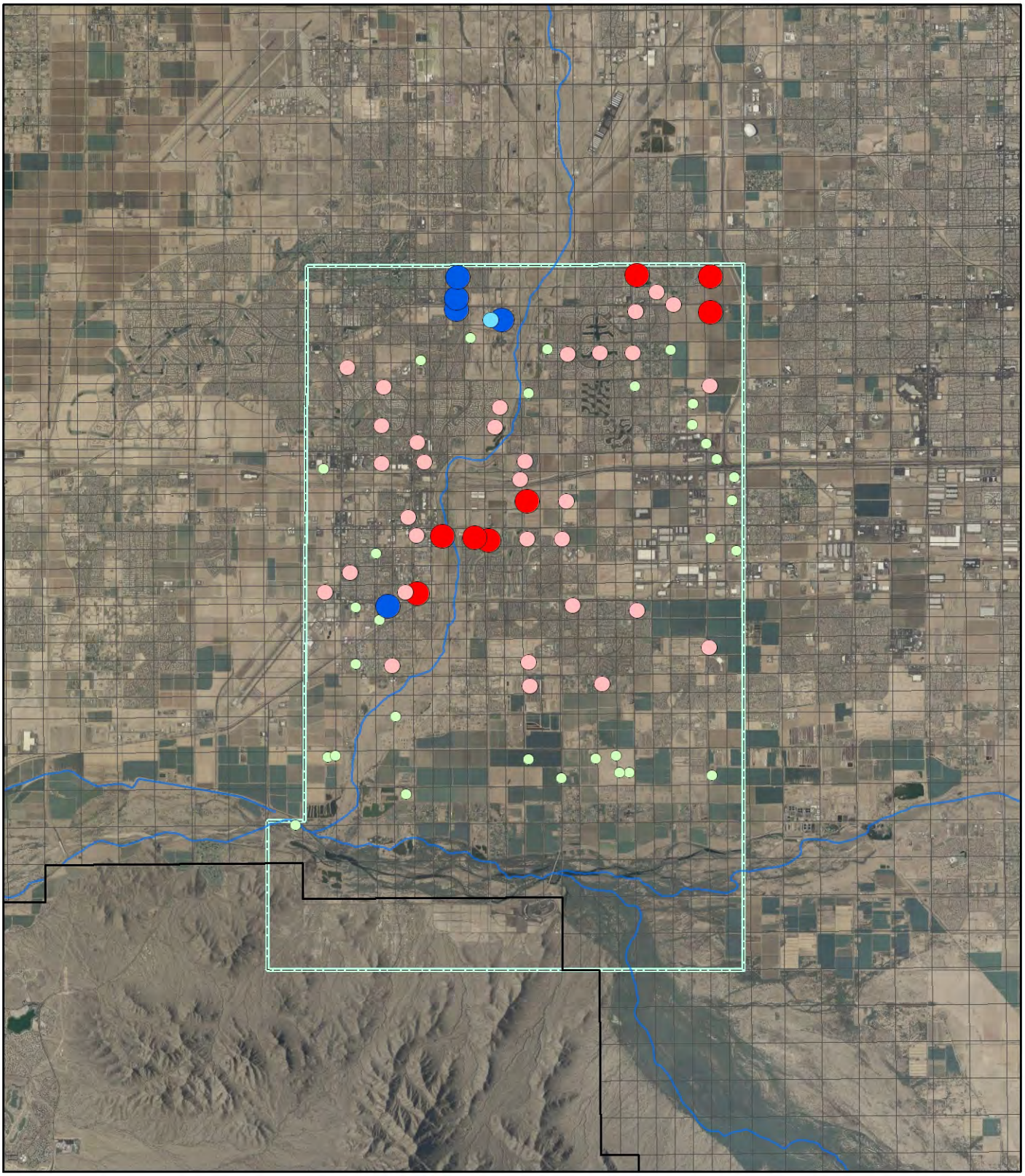
CITY OF AVONDALE, ARIZONA
WATER RESOURCE MASTER PLAN

MODEL ERROR - AVONDALE STUDY AREA
WINTER 1991/1992 WATER LEVEL SWEEP

MALCOLM PIRNIE

MAY 2010

FIGURE 20



Legend

- Major Stream
- Avondale Study Area
- Model Grid Cell

Residual Error (feet)

- Under Simulated: > (-20)
- (-20) - (-10)
- (-10) - 0
- 0 - 10
- 10 - 20
- Over Simulated: > 20

N

0 5,000 10,000 15,000 20,000 Feet

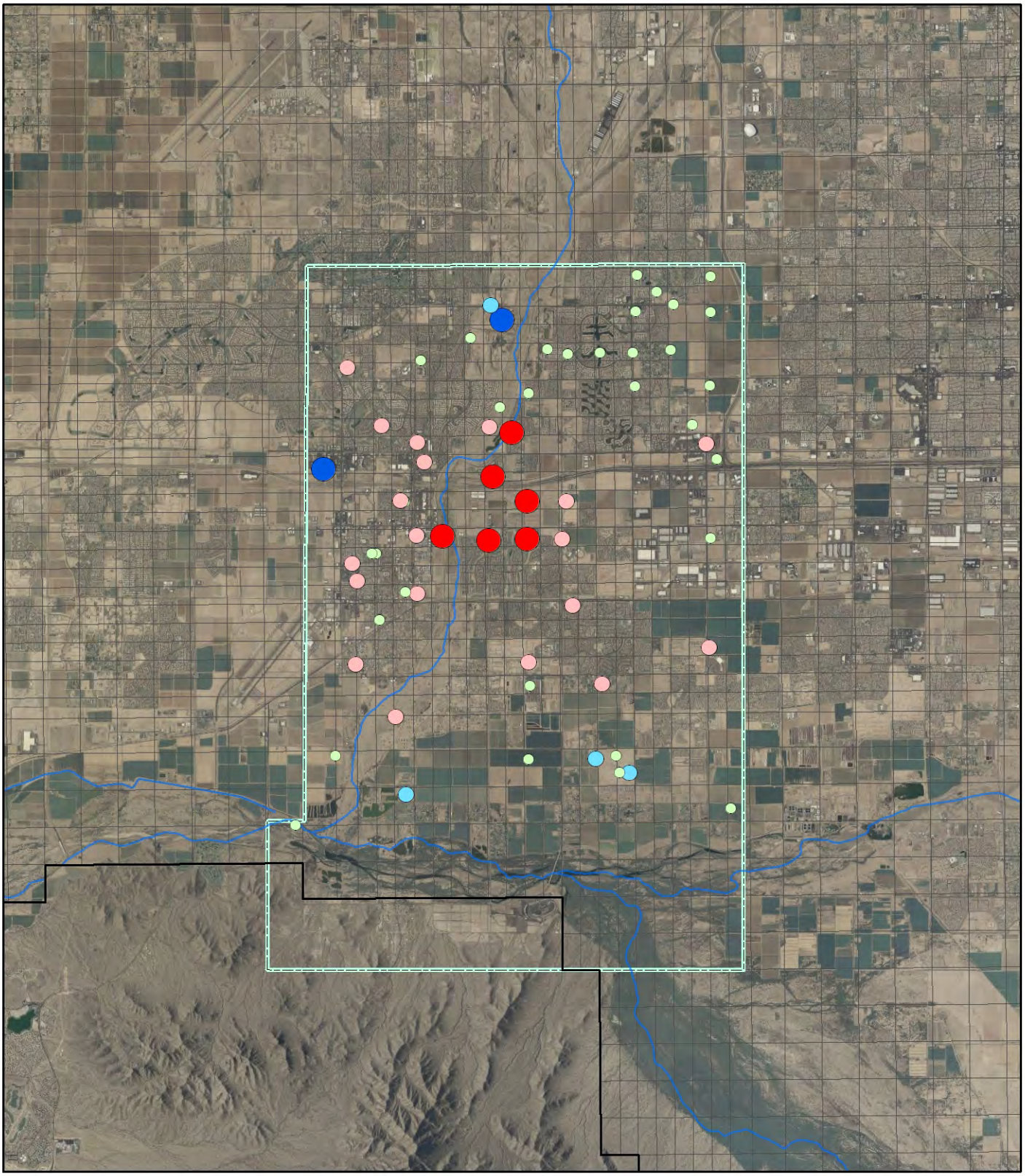
CITY OF AVONDALE, ARIZONA
WATER RESOURCE MASTER PLAN

MODEL ERROR - AVONDALE STUDY AREA
WINTER 1997/1998 WATER LEVEL SWEEP

MALCOLM PIRNIE

MAY 2010

FIGURE 21



N

0 5,000 10,000 15,000 20,000 Feet

Legend

Major Stream

Avondale Study Area

Model Grid Cell

Residual Error (feet)

Under Simulated

> (-20)

(-20) - (-10)

(-10) - 0

0 - 10

10 - 20

Over Simulated

> 20

City of Avondale

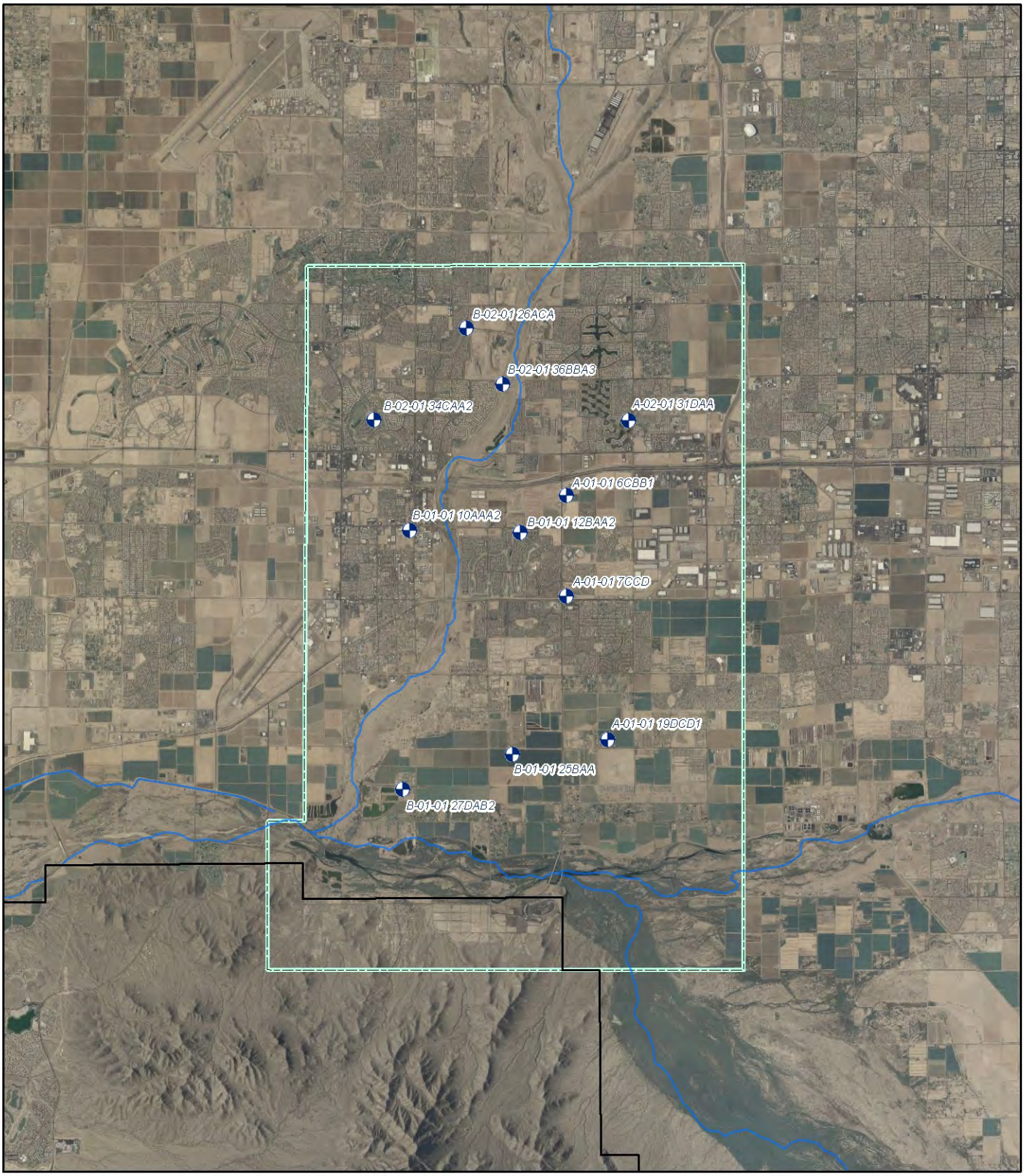
CITY OF AVONDALE, ARIZONA
WATER RESOURCE MASTER PLAN

MODEL ERROR - AVONDALE STUDY AREA
WINTER 2002/2003 WATER LEVEL SWEEP

MALCOLM PIRNIE

MAY 2010

FIGURE 22



N

0 5,000 10,000 15,000 20,000 Feet

Legend

- Major Stream
- Avondale Study Area
- ADWR Index Well Location

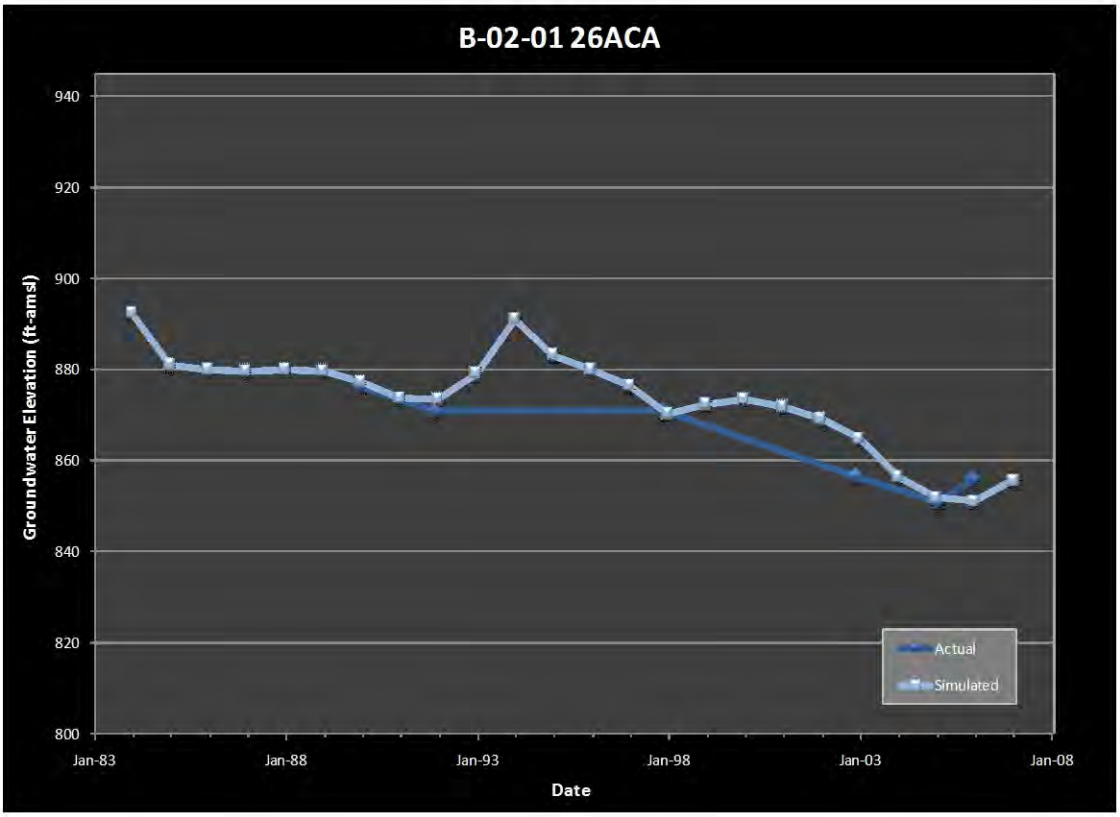
CITY OF AVONDALE, ARIZONA
WATER RESOURCE MASTER PLAN

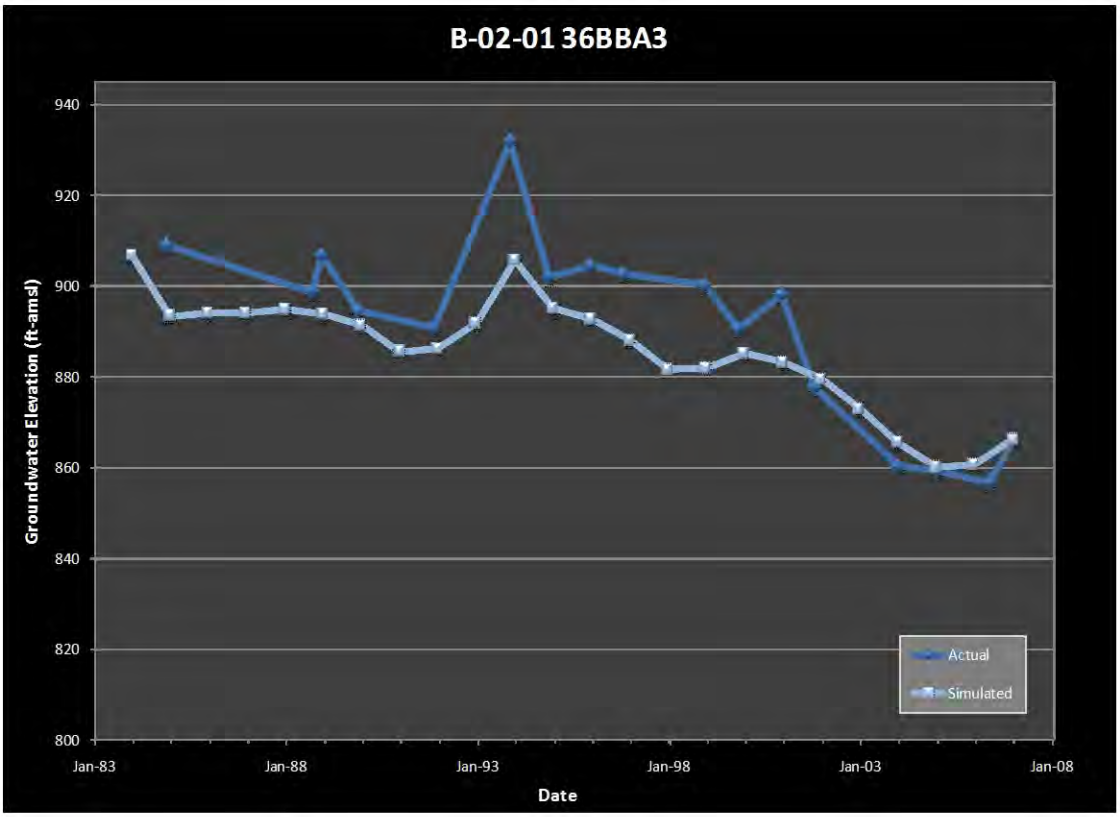
MODEL ERROR - AVONDALE STUDY AREA
ADWR INDEX WELL HYDROGRAPH LOCATIONS

MALCOLM PIRNIE

MAY 2010

FIGURE 23





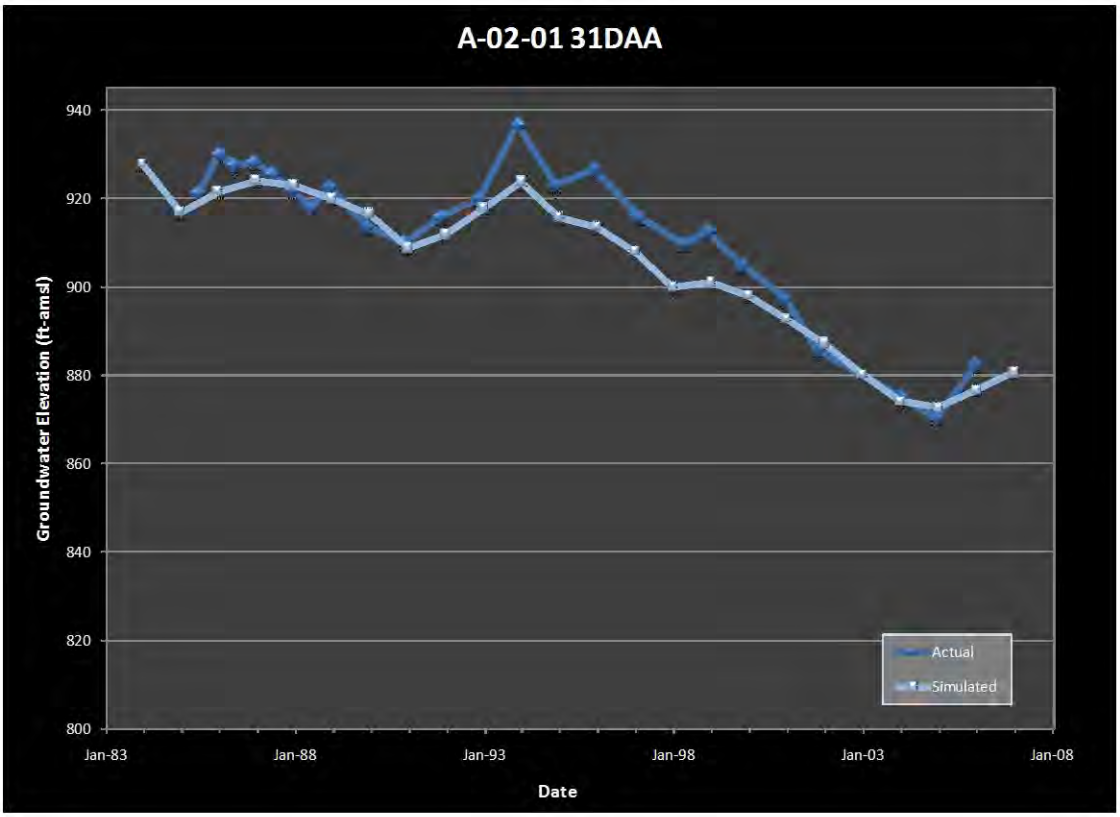
CITY OF AVONDALE, ARIZONA
WATER RESOURCE MASTER PLAN

MODEL ERROR - AVONDALE STUDY AREA
INDEX WELLS B-02-01 26ACA AND B-02-01 36BBA3 HYDROGRAPHS

MALCOLM PIRNIE

MAY 2010

FIGURE 24



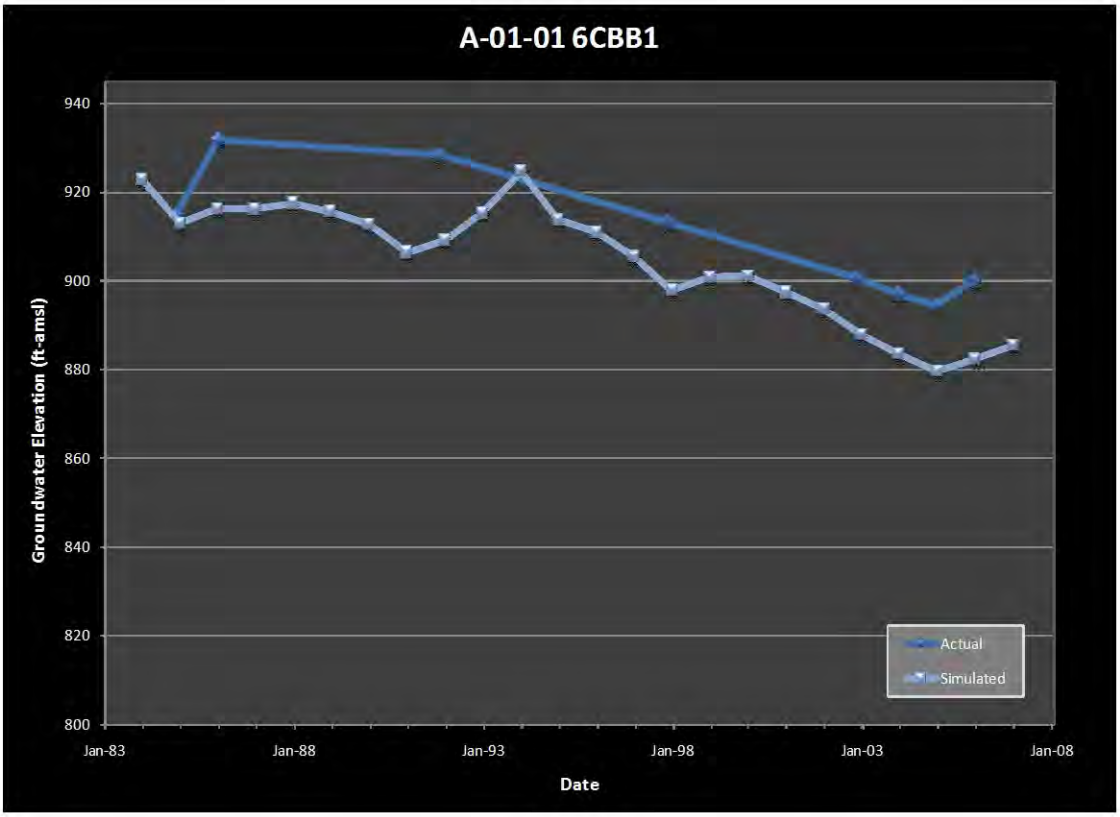
CITY OF AVONDALE, ARIZONA
WATER RESOURCE MASTER PLAN

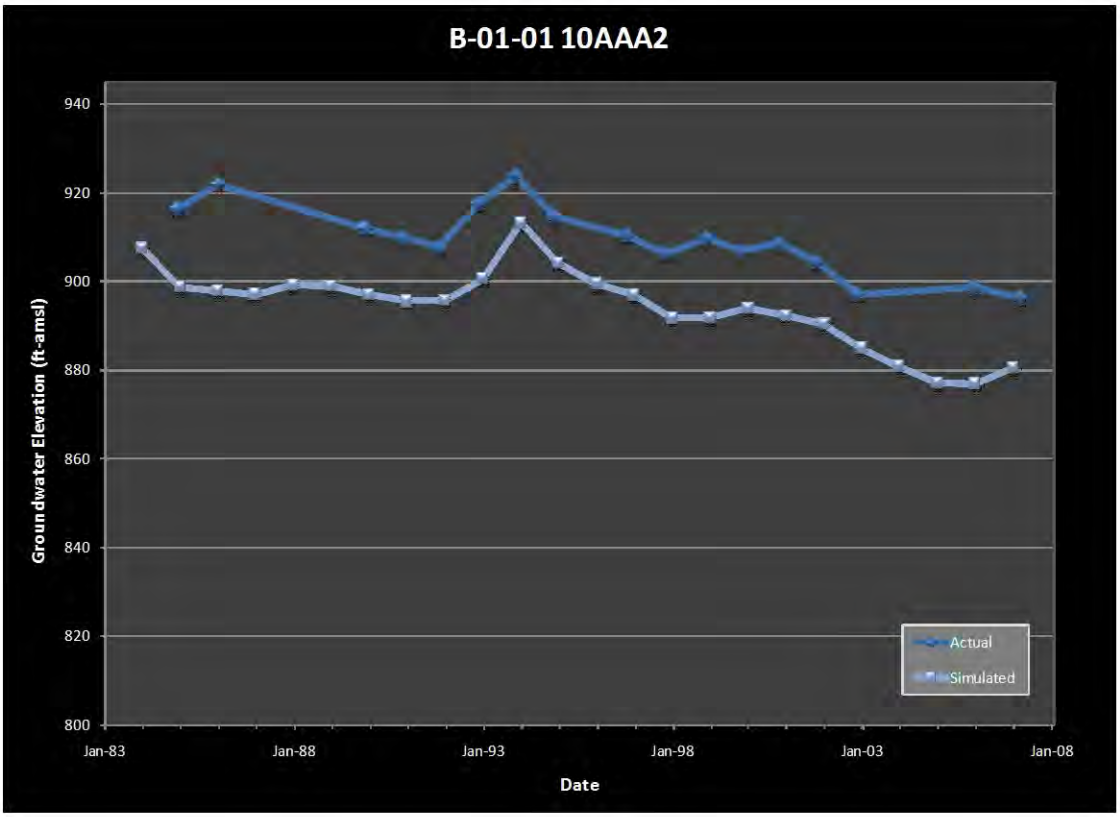
MODEL ERROR - AVONDALE STUDY AREA
INDEX WELLS B-02-01 34CAA2 AND A-02-01 31DAA HYDROGRAPHS

MALCOLM PIRNIE

MAY 2010

FIGURE 25





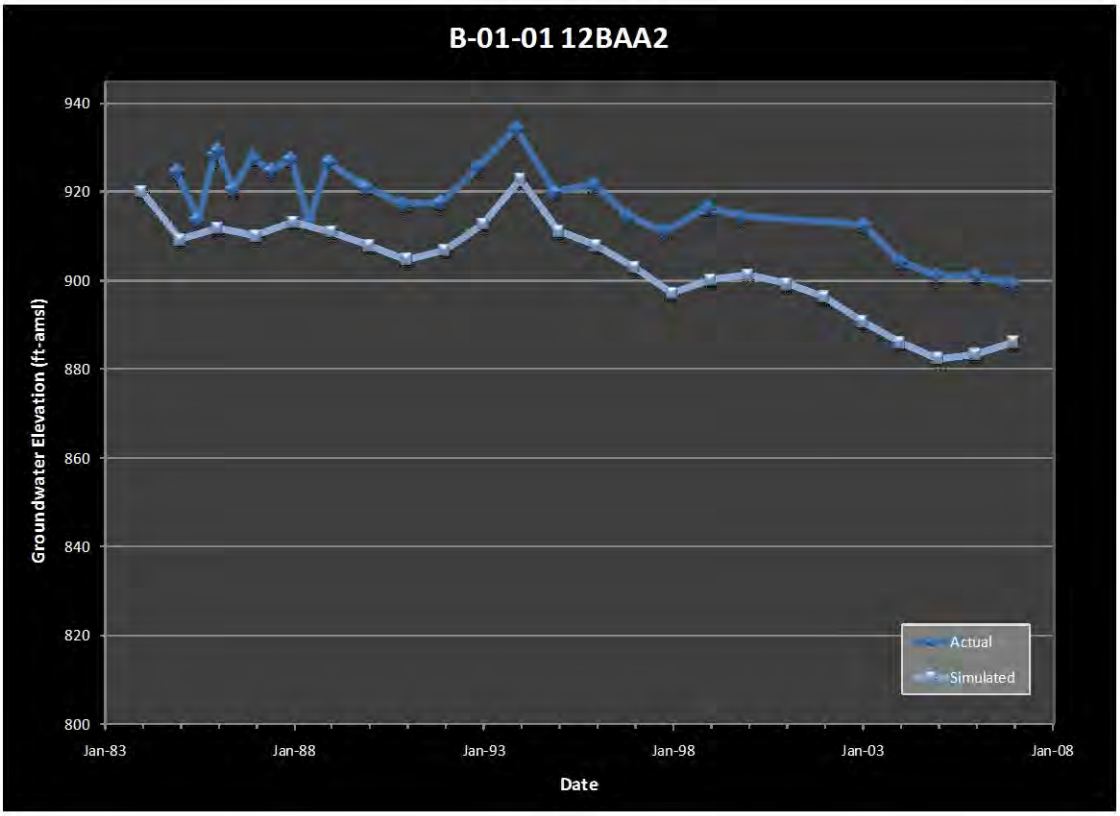
CITY OF AVONDALE, ARIZONA
WATER RESOURCE MASTER PLAN

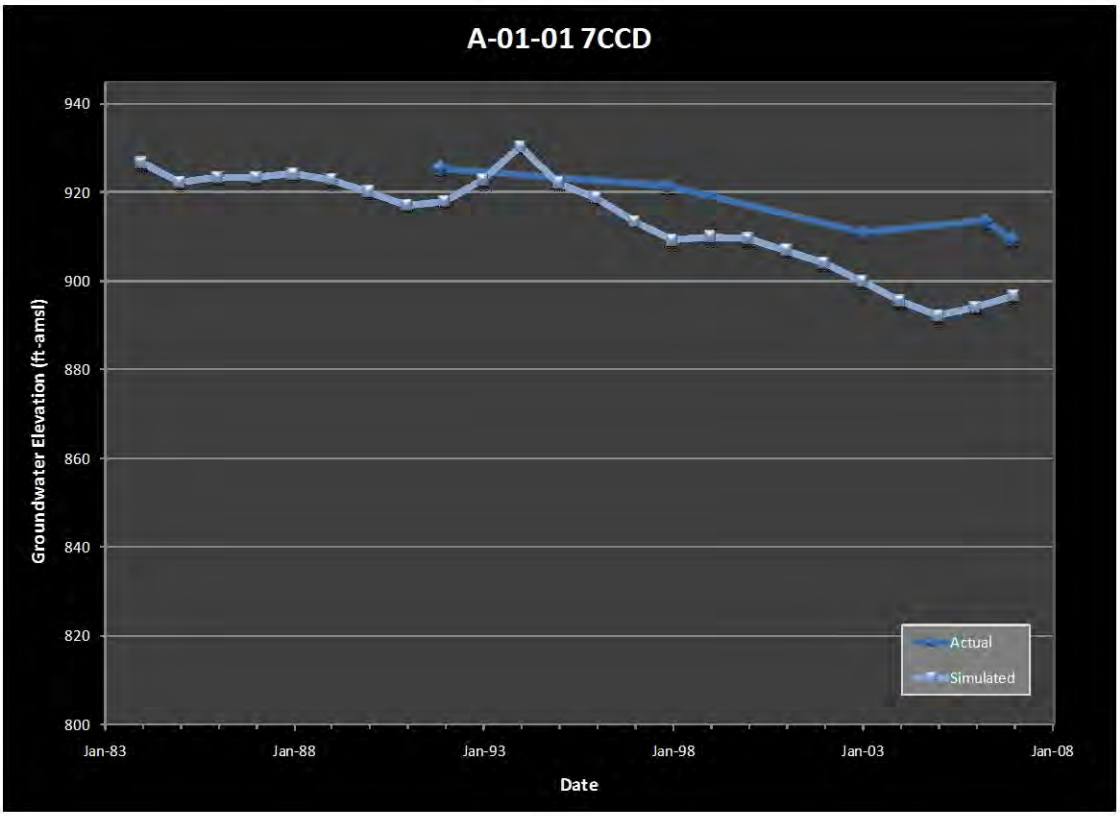
MODEL ERROR - AVONDALE STUDY AREA
INDEX WELLS A-01-01 6CBB1 AND B-01-01 10AAA2 HYDROGRAPHS

MALCOLM PIRNIE

MAY 2010

FIGURE 26





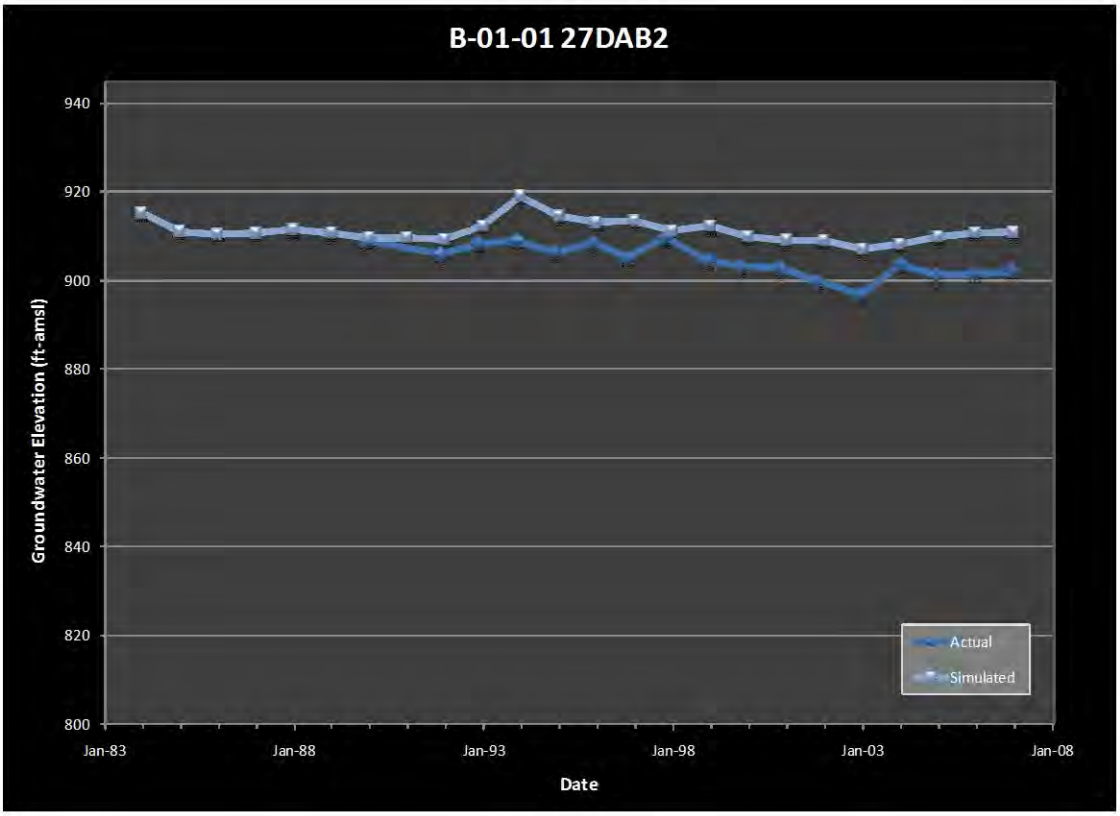
CITY OF AVONDALE, ARIZONA
WATER RESOURCE MASTER PLAN

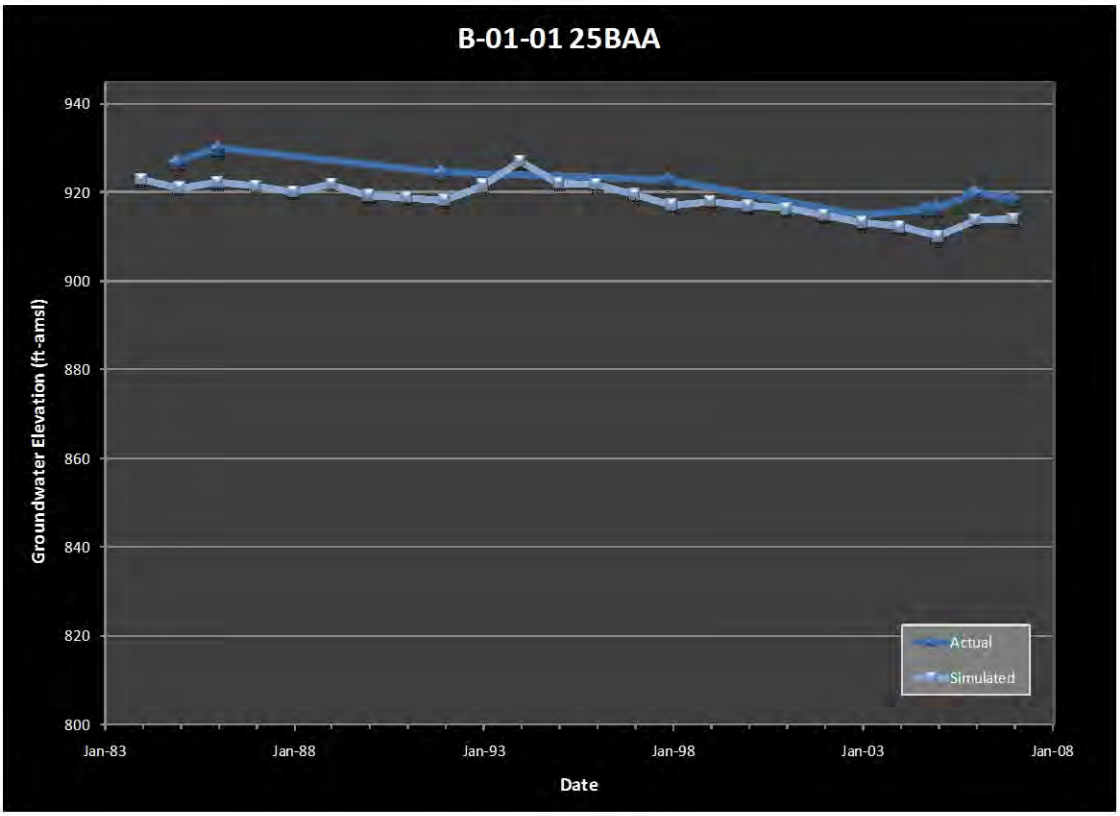
MODEL ERROR - AVONDALE STUDY AREA
INDEX WELLS B-01-01 12BAA2 AND A-01-01 7CCD HYDROGRAPHS

MALCOLM PIRNIE

MAY 2010

FIGURE 27





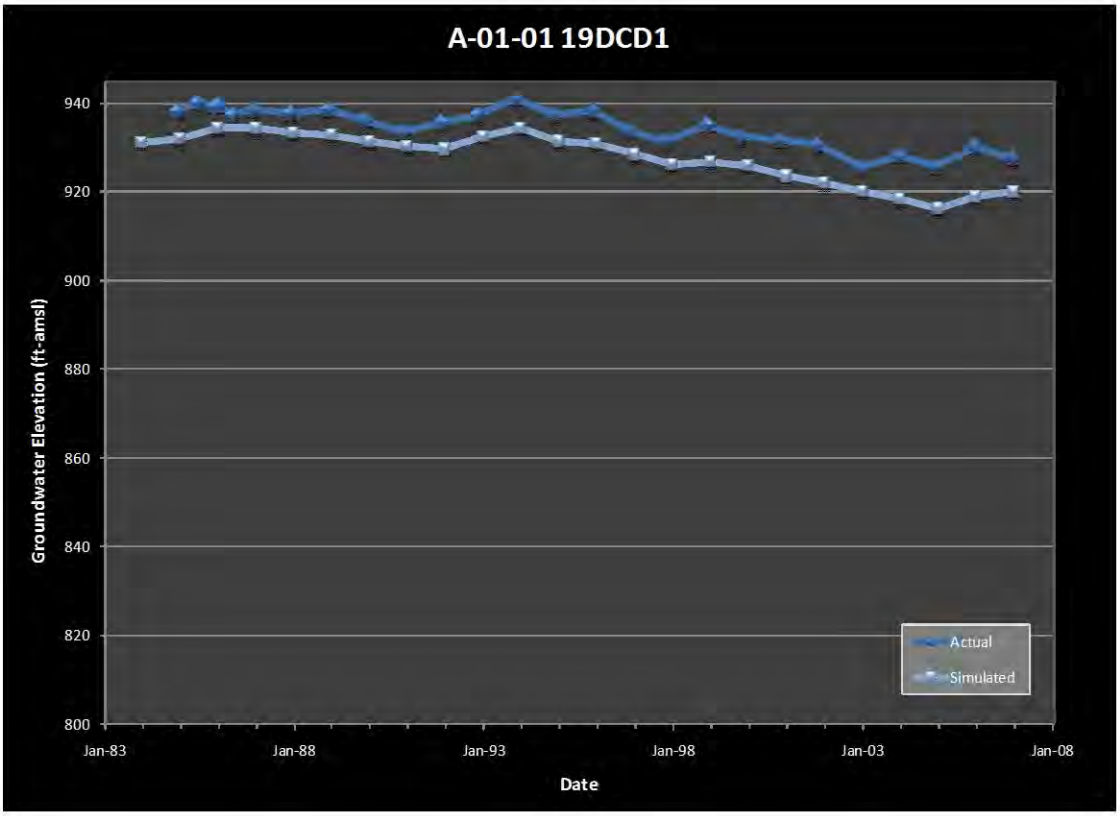
CITY OF AVONDALE, ARIZONA
WATER RESOURCE MASTER PLAN

MODEL ERROR - AVONDALE STUDY AREA
INDEX WELLS B-01-01 27DAB2 AND B-01-01 25BAA HYDROGRAPHS

MALCOLM PIRNIE

MAY 2010

FIGURE 28



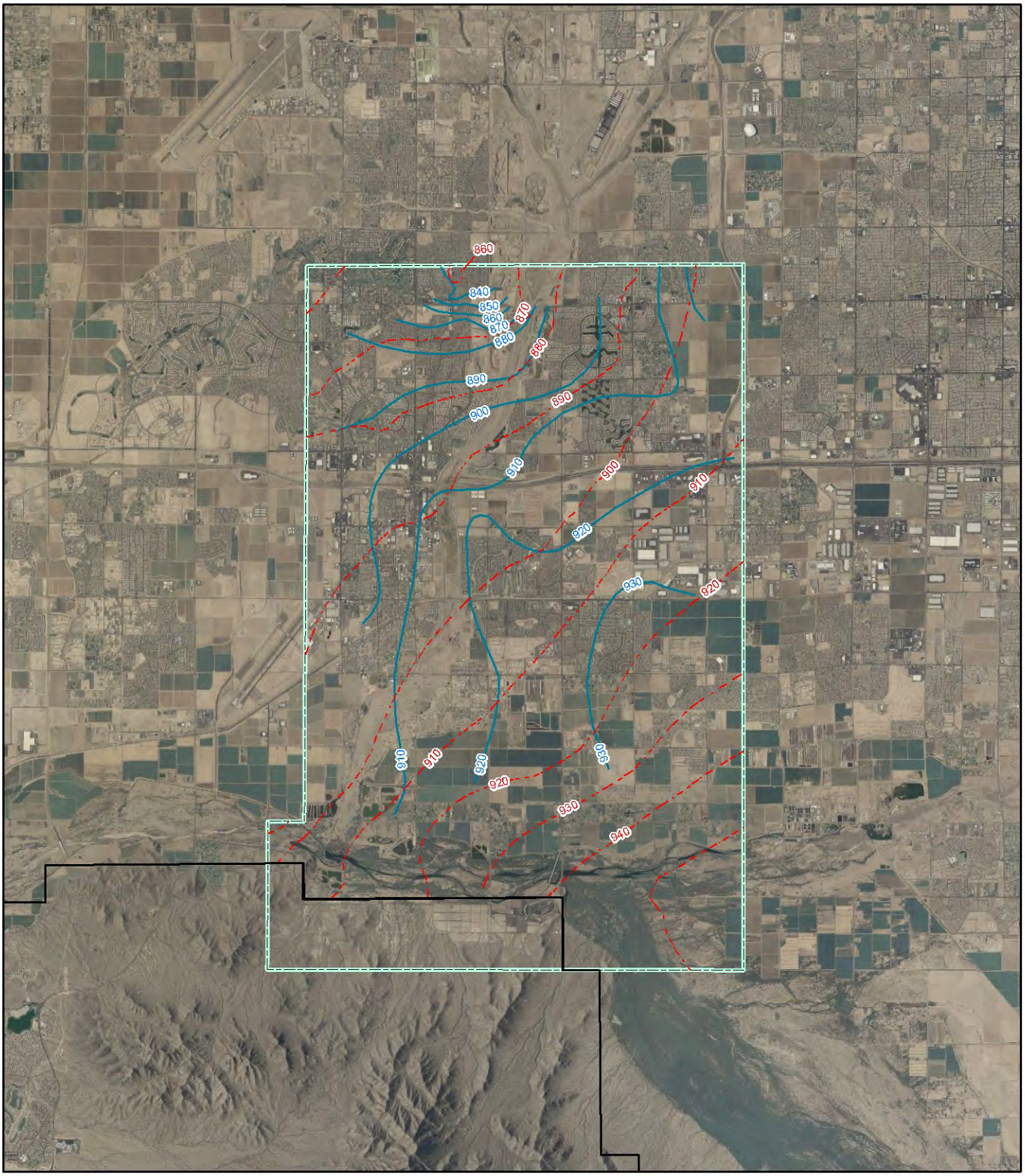
CITY OF AVONDALE, ARIZONA
WATER RESOURCE MASTER PLAN

MODEL ERROR - AVONDALE STUDY AREA
INDEX WELL B-02-01 26ACA HYDROGRAPHS

MALCOLM PIRNIE

MAY 2010

FIGURE 29



N

0 5,000 10,000 15,000 20,000 Feet

Legend

- Winter 1997/1998 Groundwater Elevation Contour
- Winter 1997/1998 Model Simulated Groundwater Elevation Contour
- Avondale Study Area

City of Avondale

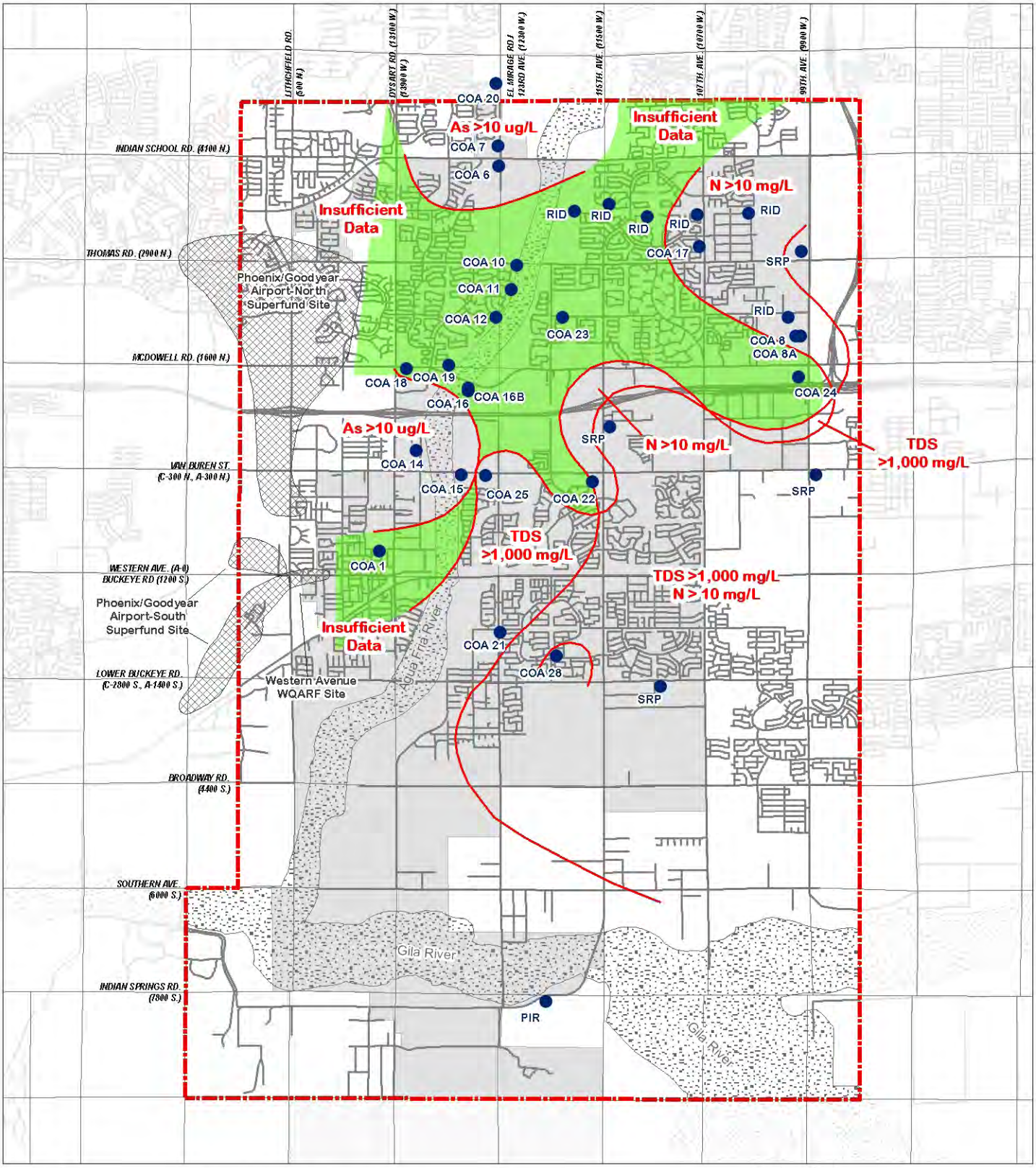
CITY OF AVONDALE, ARIZONA
WATER RESOURCE MASTER PLAN

WINTER 1997/1998 SIMULATED VS OBSERVED FLOW PATTERNS
AVONDALE STUDY AREA

MALCOLM PIRNIE

MAY 2010

FIGURE 30



Superfund Site Programs

WQARF:
Western Avenue Site

Superfund:
Phoenix/Goodyear Airport-North

Phoenix/Goodyear Airport-South

Major Contaminants:
Tetrachloroethene (~60-110 feet below land surface)

Trichloroethene, Perchlorates (~70-130 feet below land surface)

Trichloroethene, Chromium (~0-360 feet below land surface)

Explanation

- COA 20 — Water quality data point
- Assumed concentration contours:
  - 1000 mg/L total dissolved solids
  - 10 mg/L nitrate
  - 10 ug/L arsenic
- Areas with most favorable water quality
- Study Area

N

0 1,750 3,500 7,000
Feet

City of Avondale

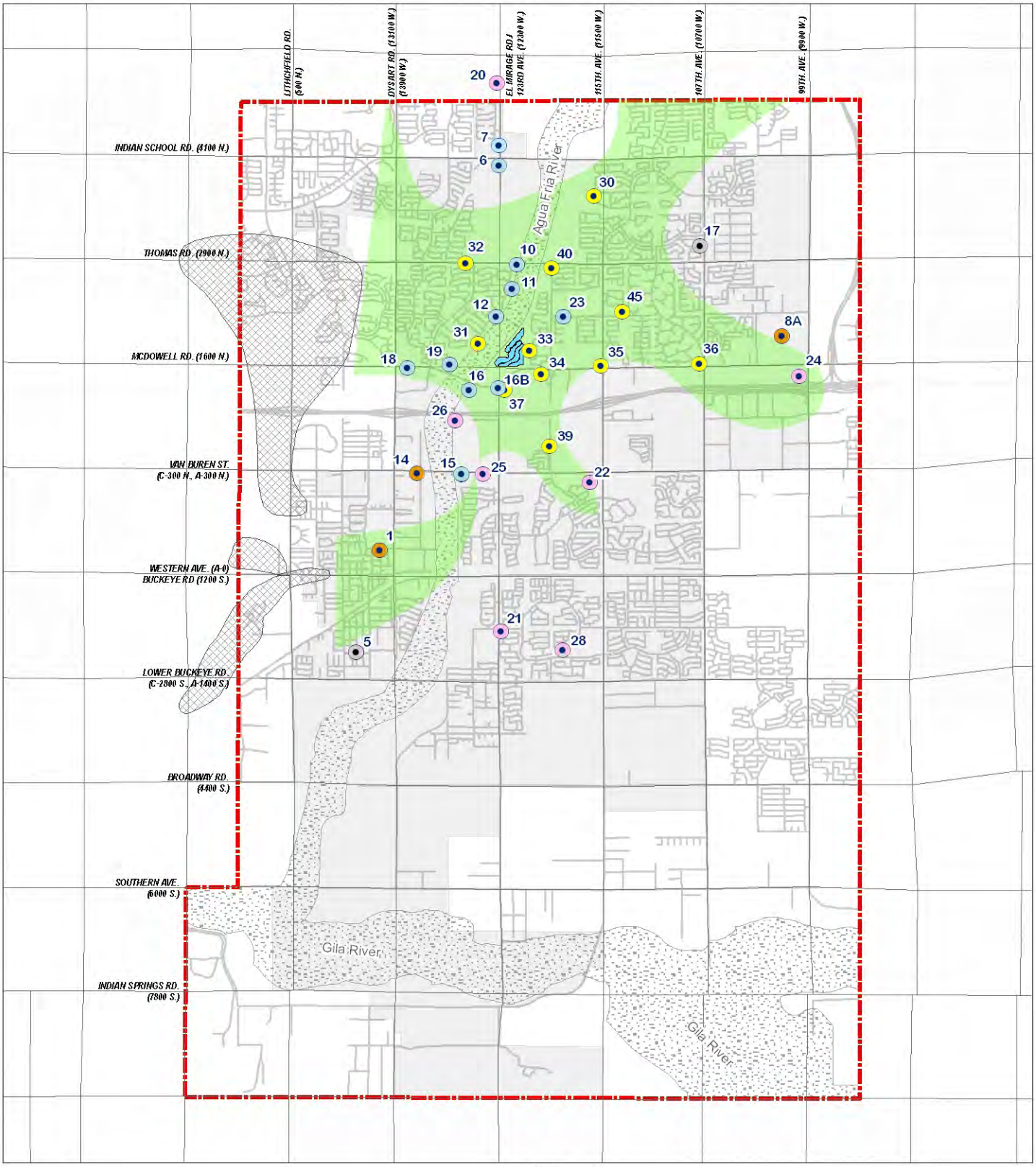
CITY OF AVONDALE, ARIZONA
WATER RESOURCE MASTER PLAN

WATER QUALITY FAVORABILITY MAP

MALCOLM PIRNIE

MAY 2010

FIGURE 31



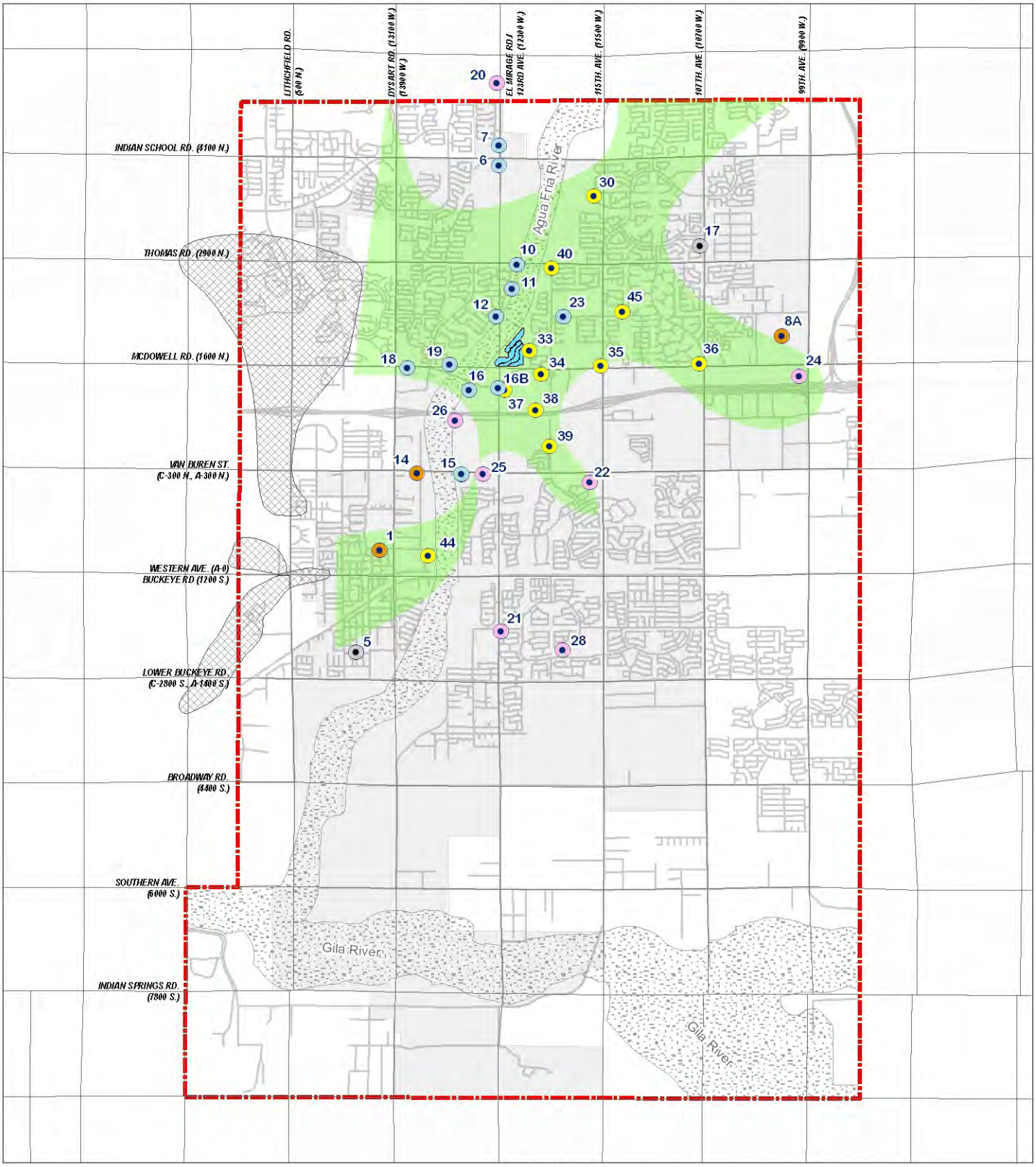
CITY OF AVONDALE, ARIZONA
WATER RESOURCE MASTER PLAN

ALTERNATIVE 1
WELL LAYOUT MAP

MALCOLM PIRNIE

MAY 2010

FIGURE 32



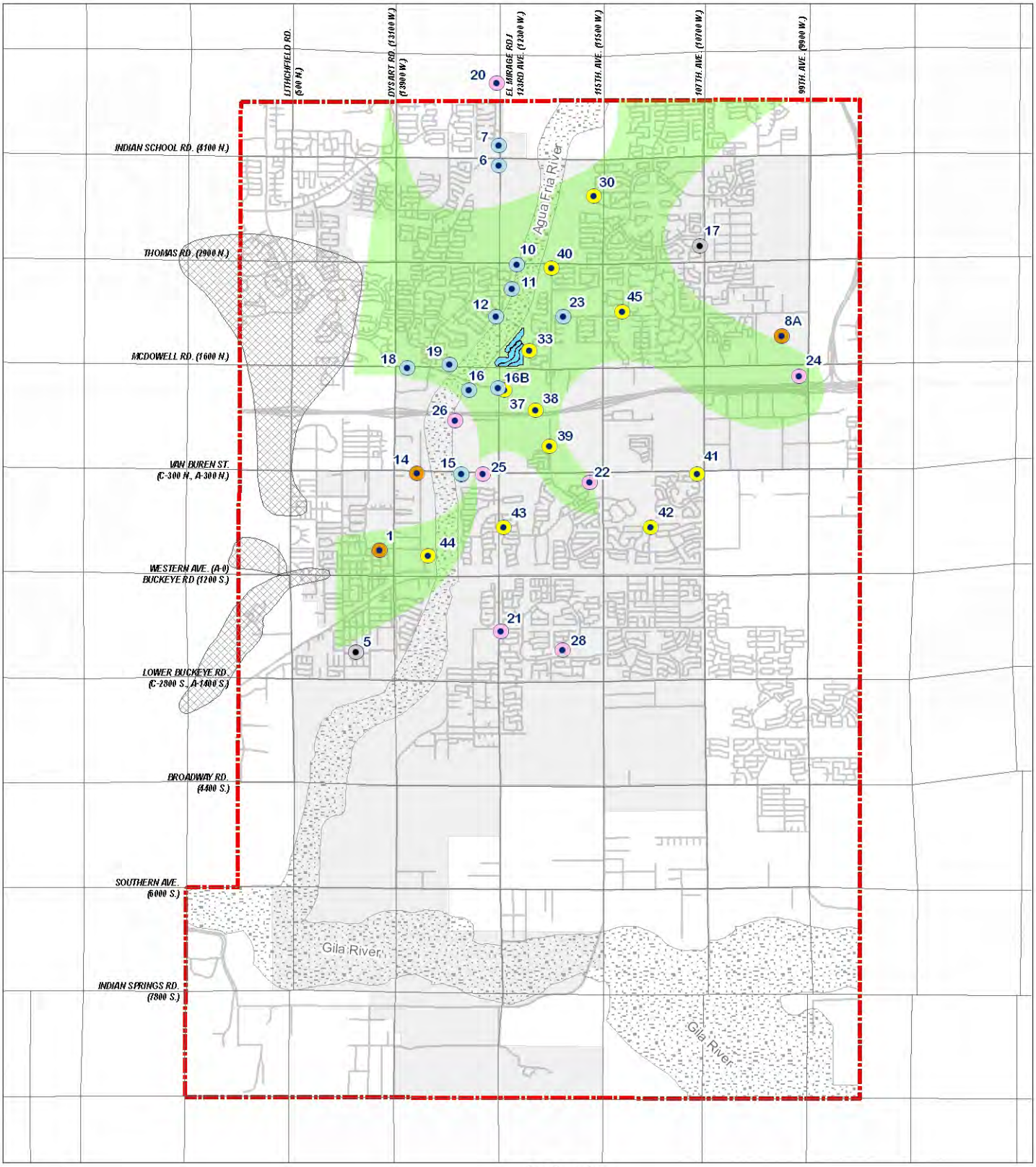
CITY OF AVONDALE, ARIZONA
WATER RESOURCE MASTER PLAN

ALTERNATIVE 2
WELL LAYOUT MAP

MALCOLM PIRNIE

MAY 2010

FIGURE 33



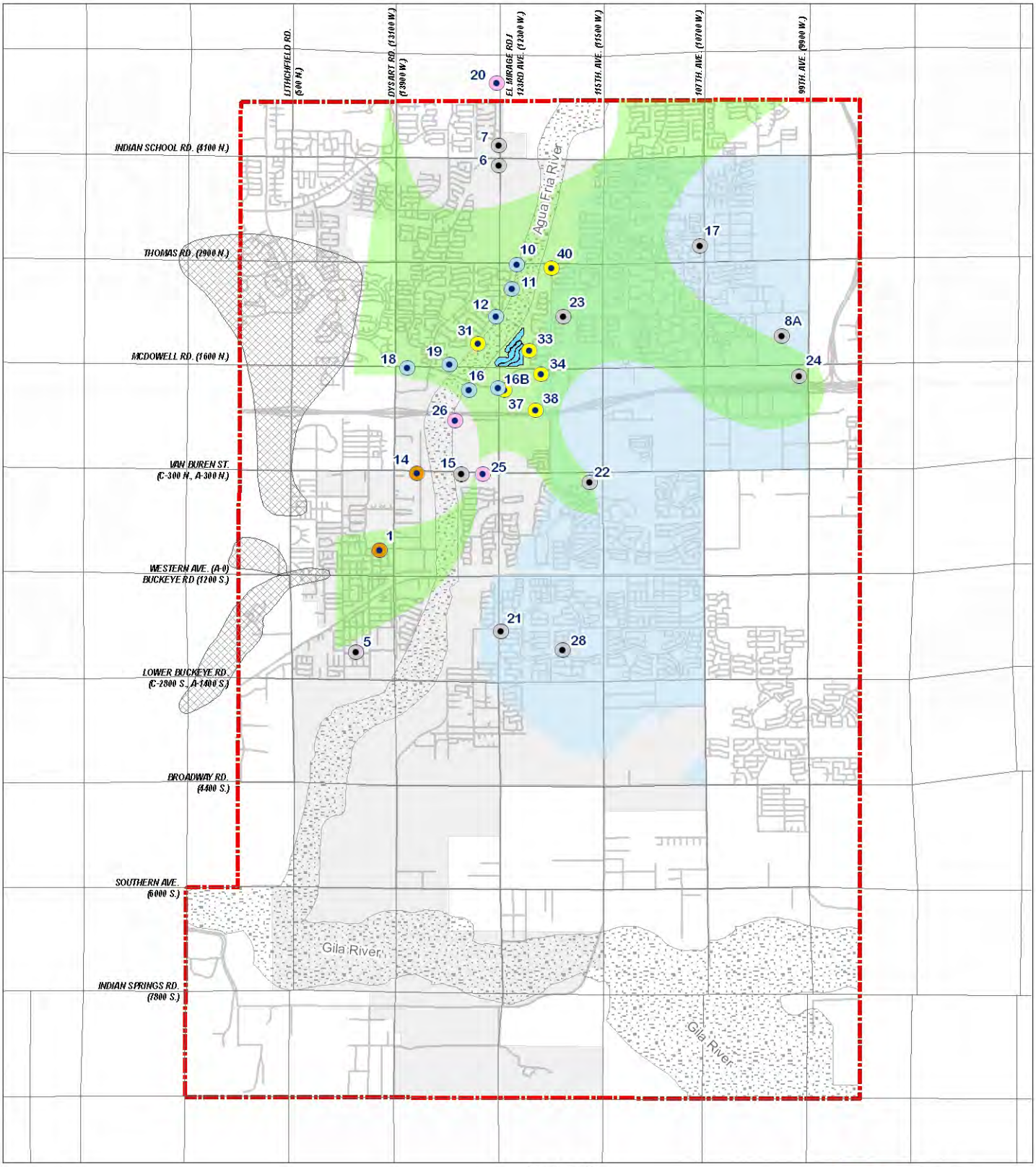
CITY OF AVONDALE, ARIZONA
WATER RESOURCE MASTER PLAN

ALTERNATIVE 3
WELL LAYOUT MAP

MALCOLM PIRNIE

MAY 2010

FIGURE 34



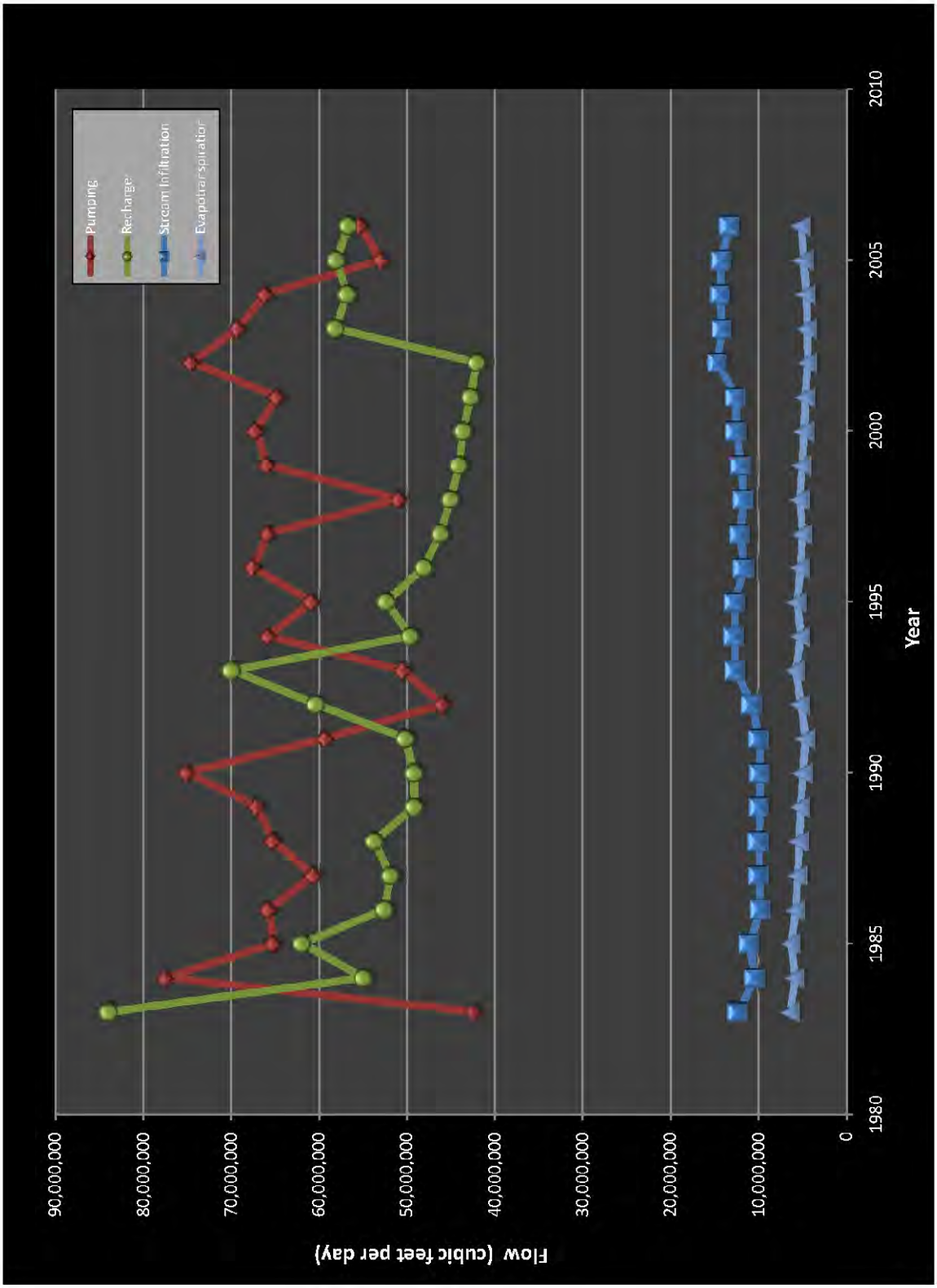
CITY OF AVONDALE, ARIZONA
WATER RESOURCE MASTER PLAN

ALTERNATIVES 4 AND 5
WELL LAYOUT MAP

MALCOLM PIRNIE

MAY 2010

FIGURE 35



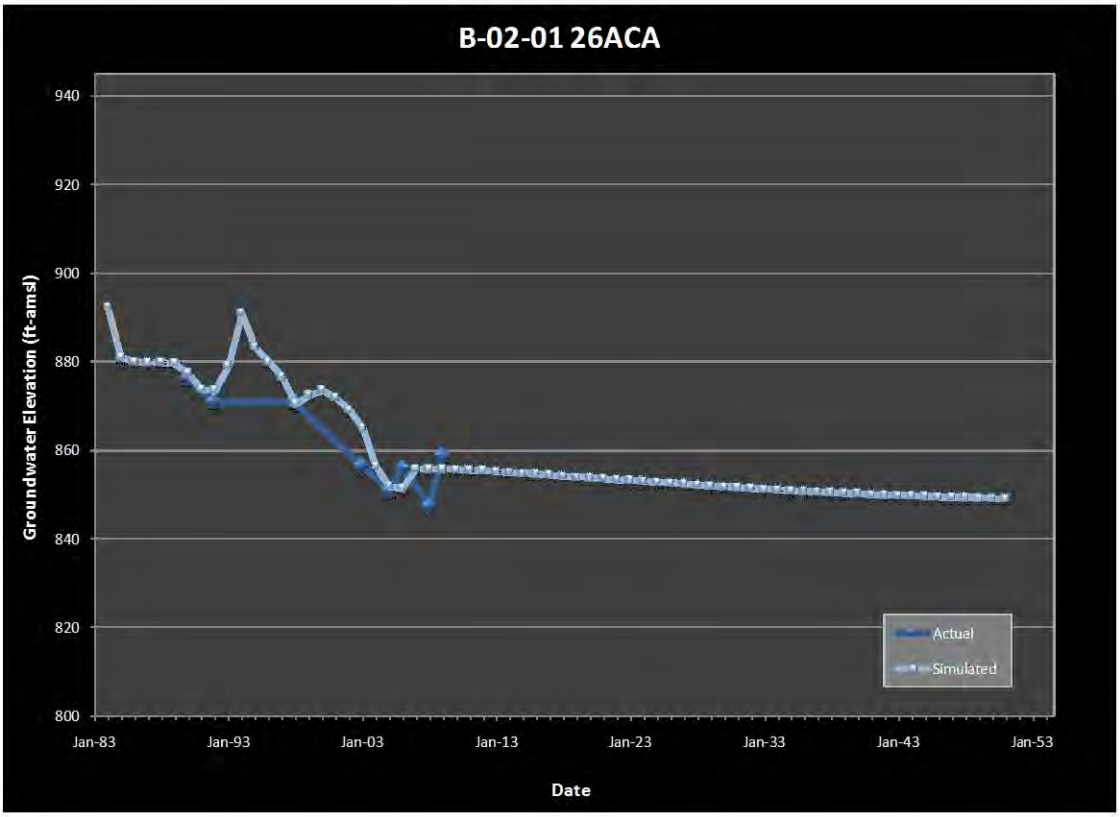
CITY OF AVONDALE, ARIZONA
WATER RESOURCE MASTER PLAN

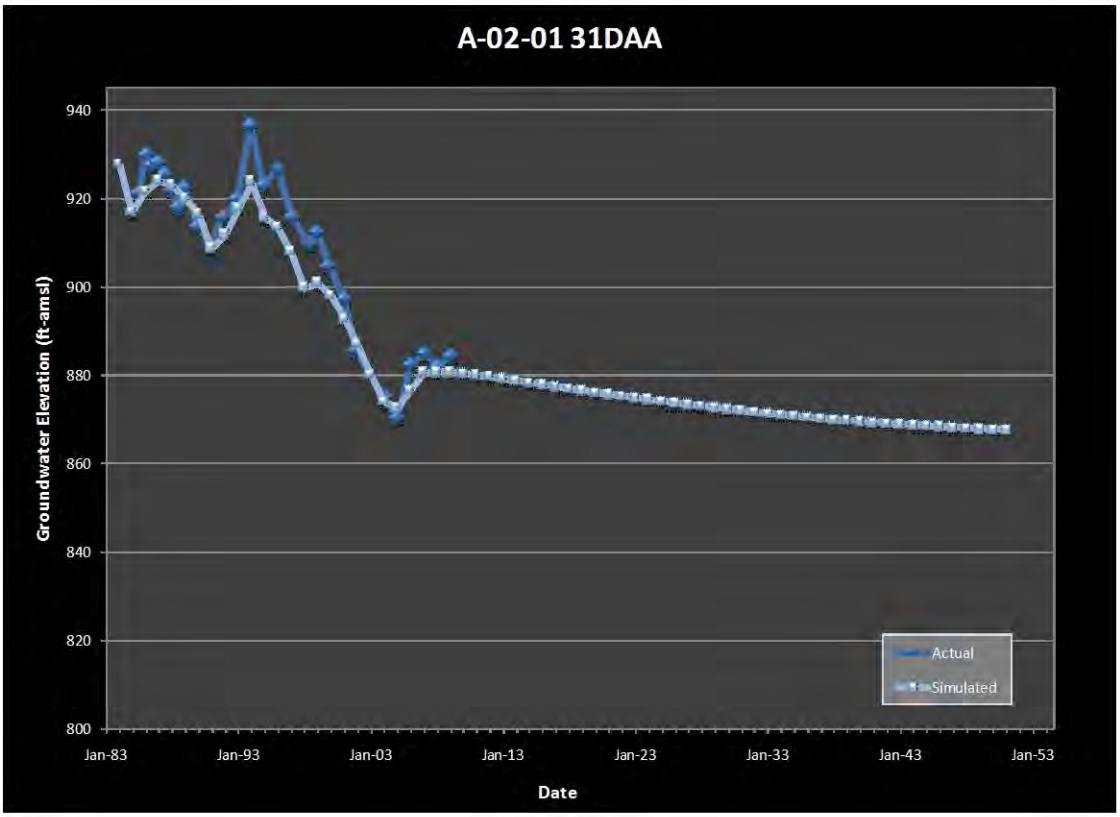
SIMULATED REGIONAL STRESS CONDITIONS 1983 - 2006

MALCOLM PIRNIE

MAY 2010

FIGURE 36





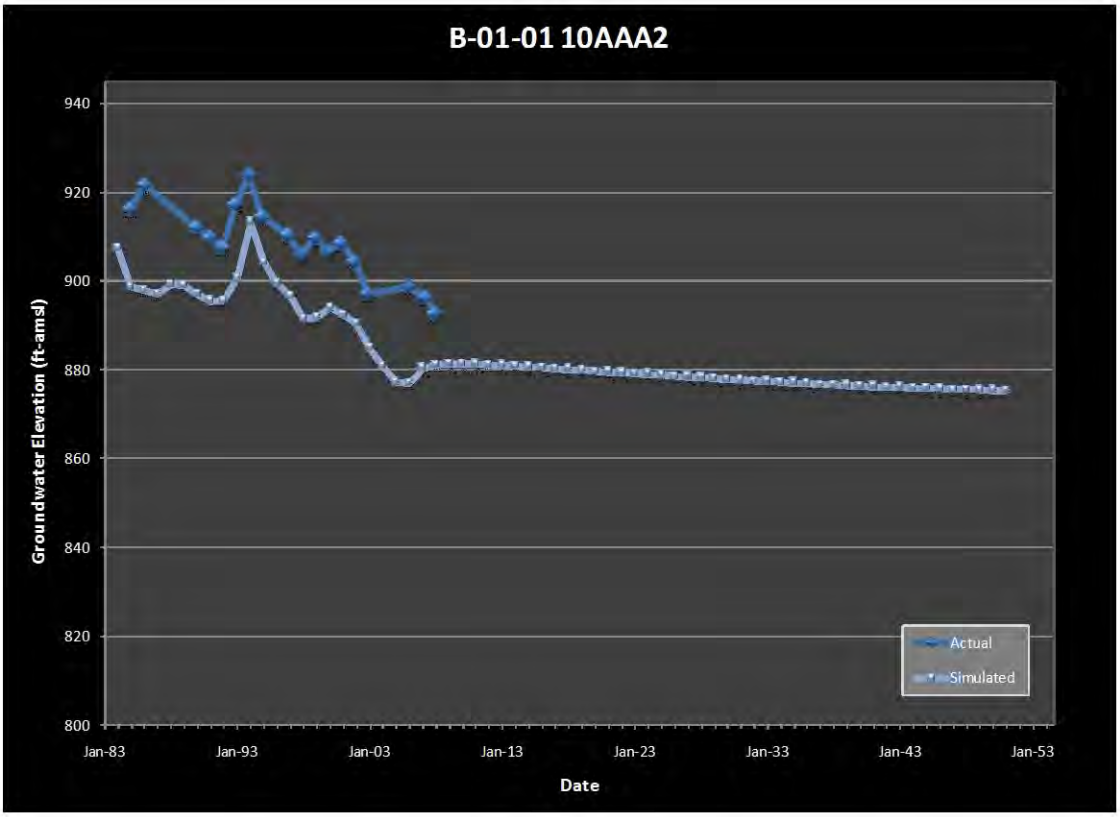
CITY OF AVONDALE, ARIZONA
WATER RESOURCE MASTER PLAN

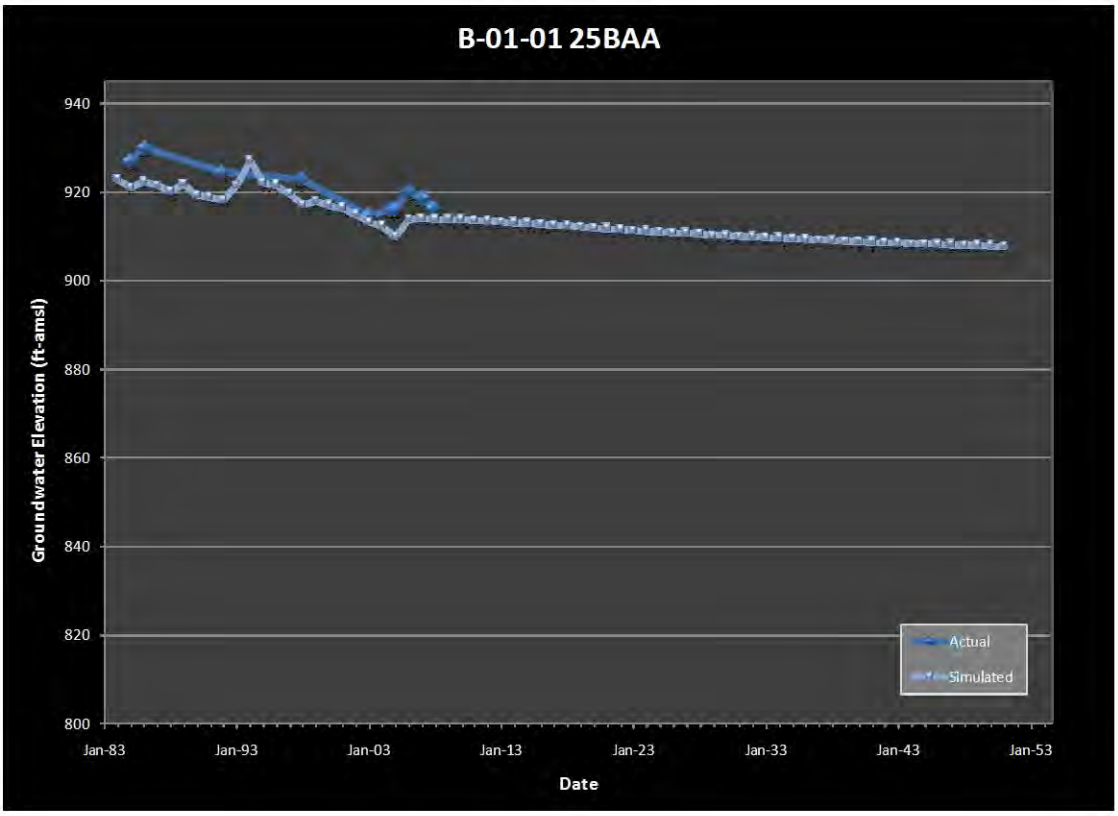
BASE CASE FUTURE SIMULATED WATER LEVEL TRENDS
INDEX WELL B-02-01 26ACA AND A-02-01 31DAA HYDROGRAPHS

MALCOLM PIRNIE

MAY 2010

FIGURE 37





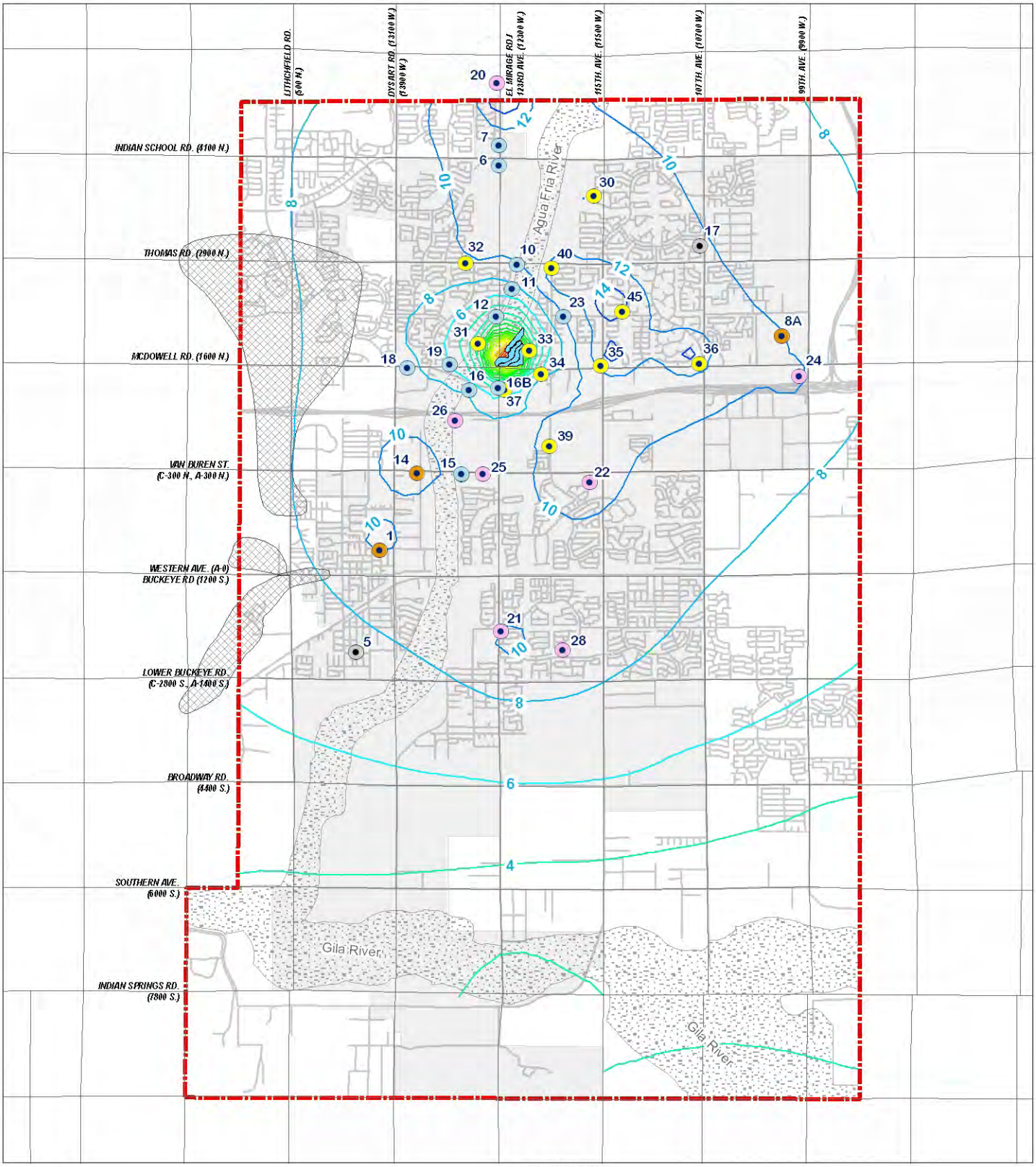
CITY OF AVONDALE, ARIZONA
WATER RESOURCE MASTER PLAN

BASE CASE FUTURE SIMULATED WATER LEVEL TRENDS
INDEX WELL B-01-01 10AAA2 AND B-01-01 25BAA HYDROGRAPHS

MALCOLM PIRNIE

MAY 2010

FIGURE 38



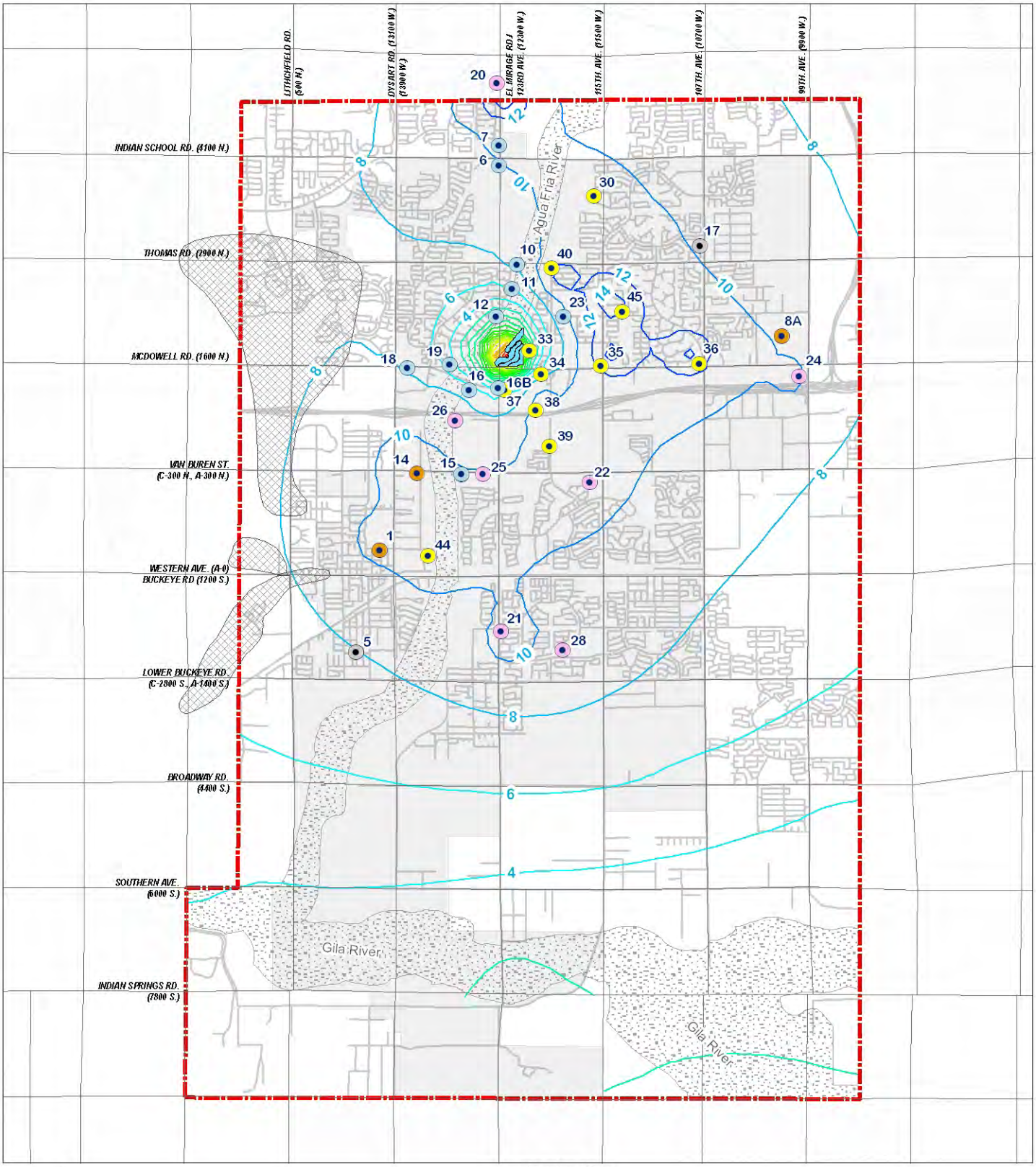
CITY OF AVONDALE, ARIZONA
WATER RESOURCE MASTER PLAN

ALTERNATIVE 1
2050 DRAWDOWN MAP

MALCOLM PIRNIE

MAY 2010

FIGURE 39



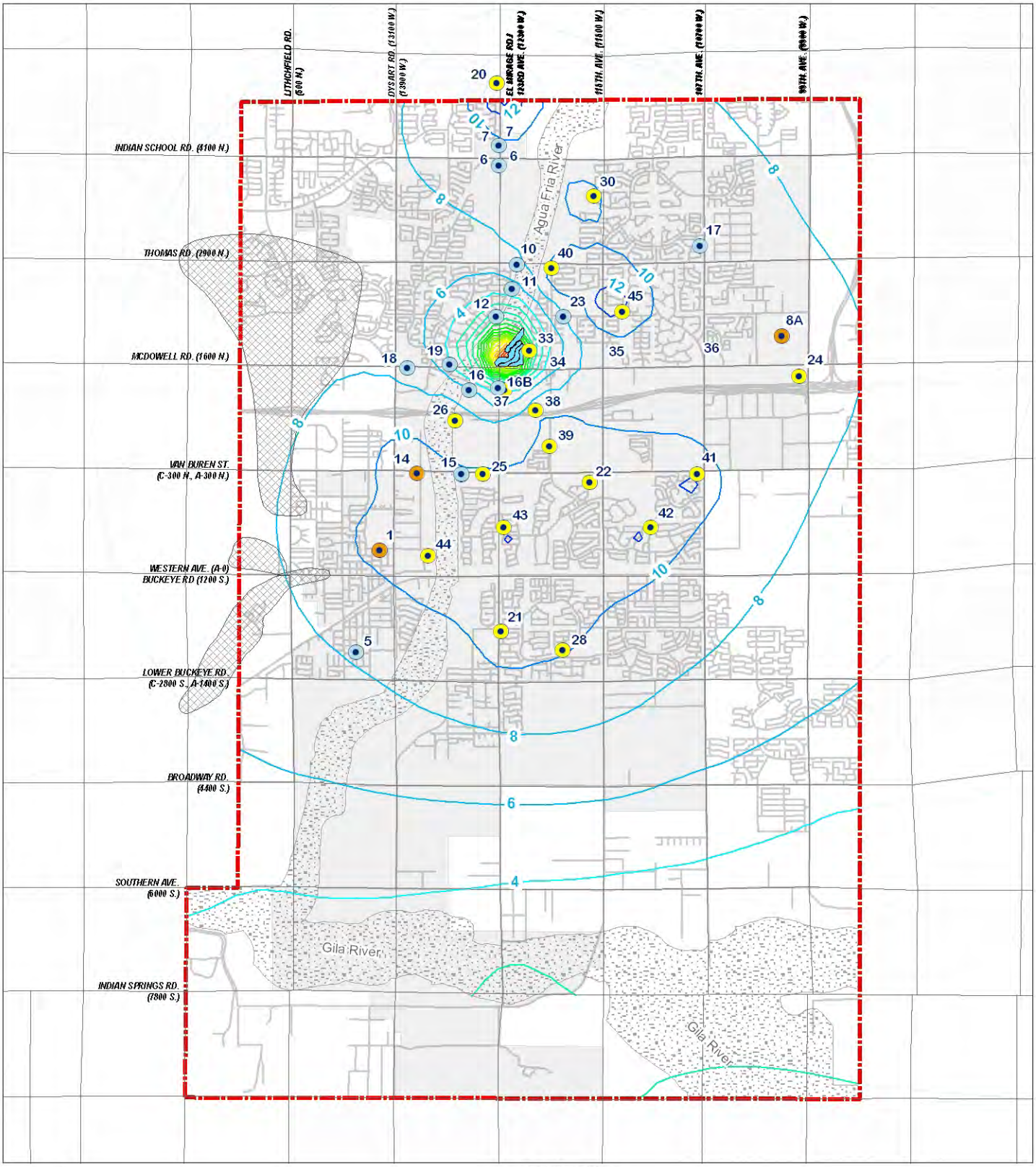
CITY OF AVONDALE, ARIZONA
WATER RESOURCE MASTER PLAN

ALTERNATIVE 2
2050 DRAWDOWN MAP

MALCOLM PIRNIE

MAY 2010

FIGURE 40



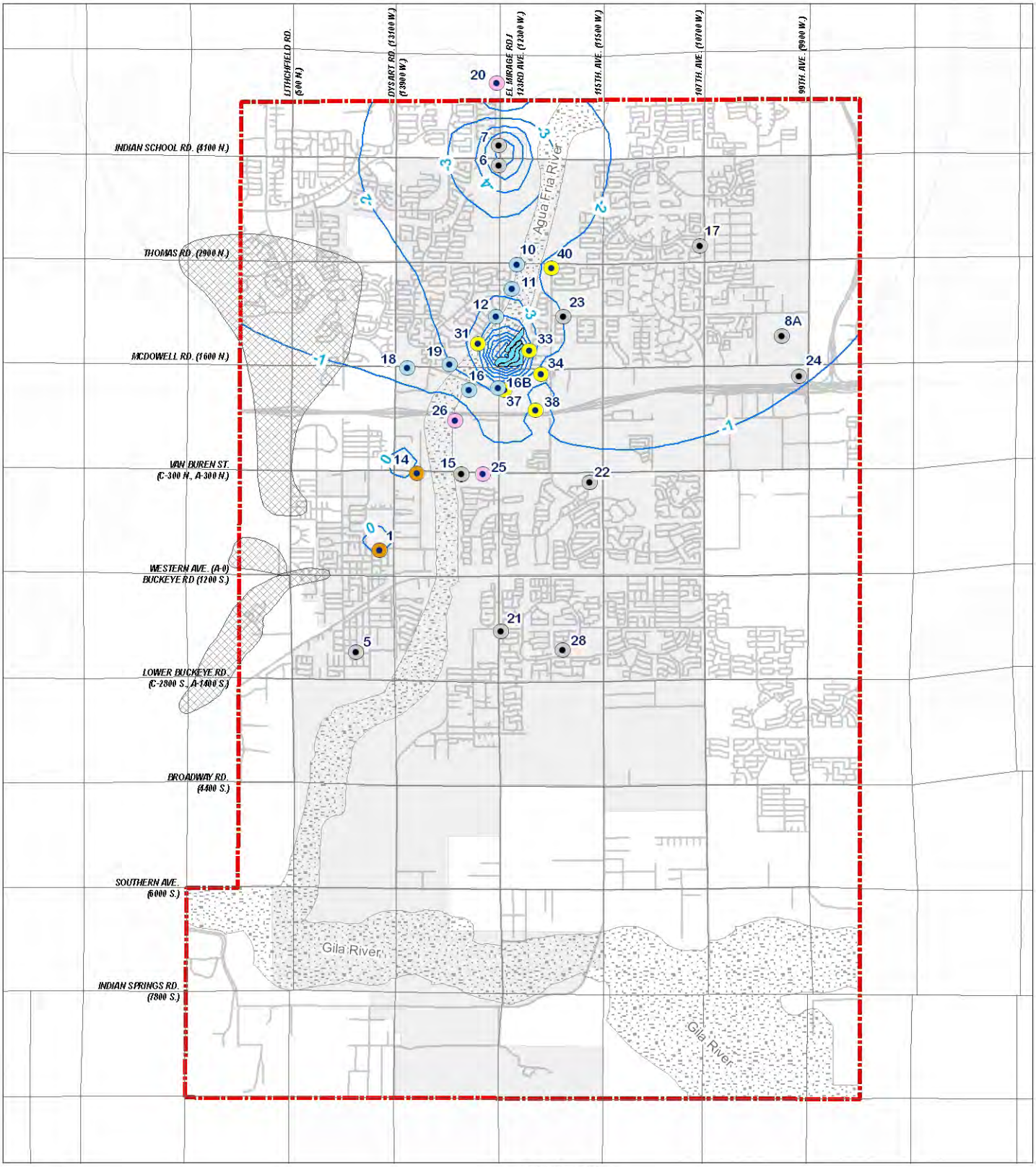
CITY OF AVONDALE, ARIZONA
WATER RESOURCE MASTER PLAN

ALTERNATIVE 3
2050 DRAWDOWN MAP

MALCOLM PIRNIE

MAY 2010

FIGURE 41



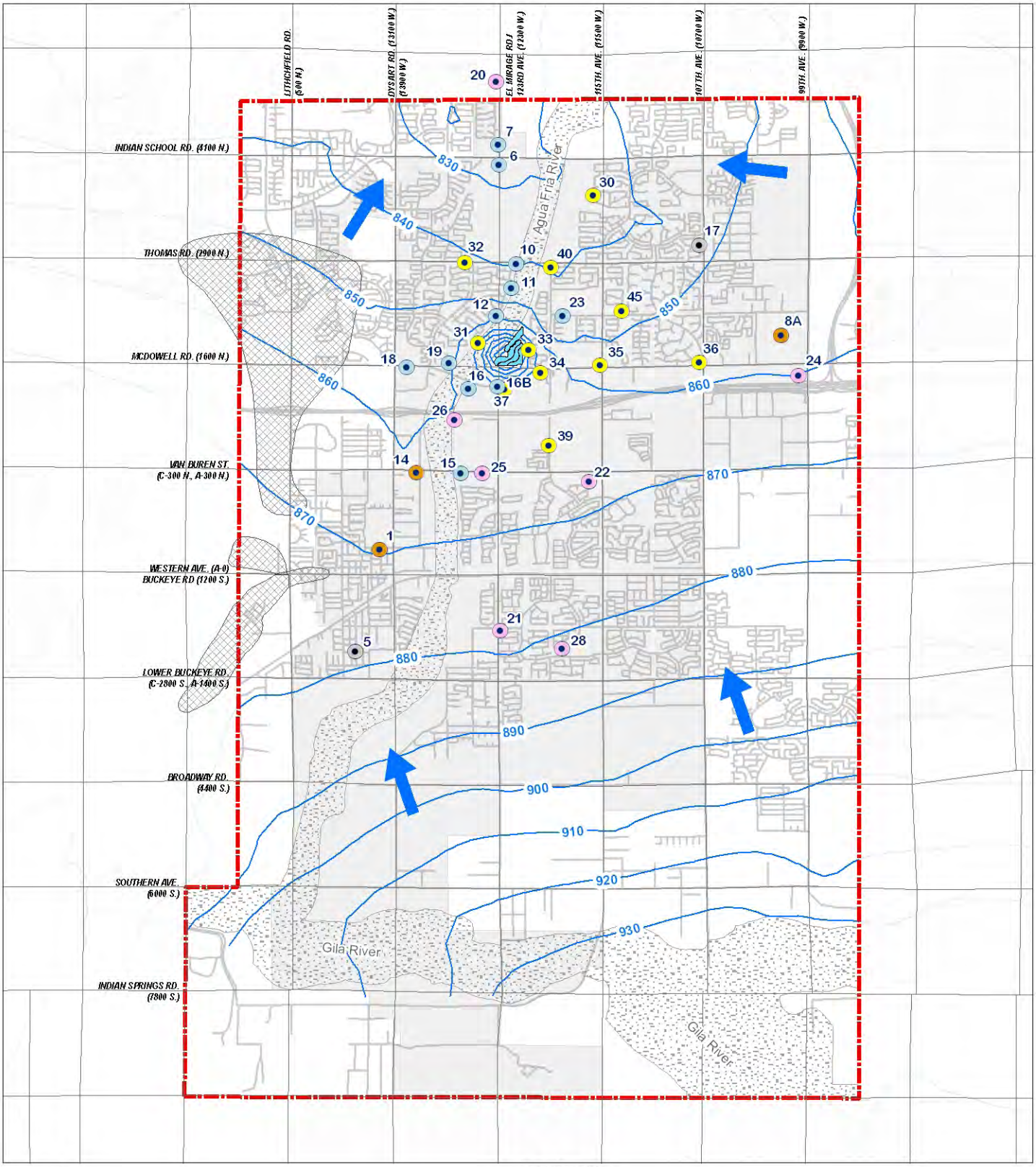
CITY OF AVONDALE, ARIZONA
WATER RESOURCE MASTER PLAN

ALTERNATIVES 4 AND 5
2050 DRAWDOWN MAP

MALCOLM PIRNIE

MAY 2010

FIGURE 42



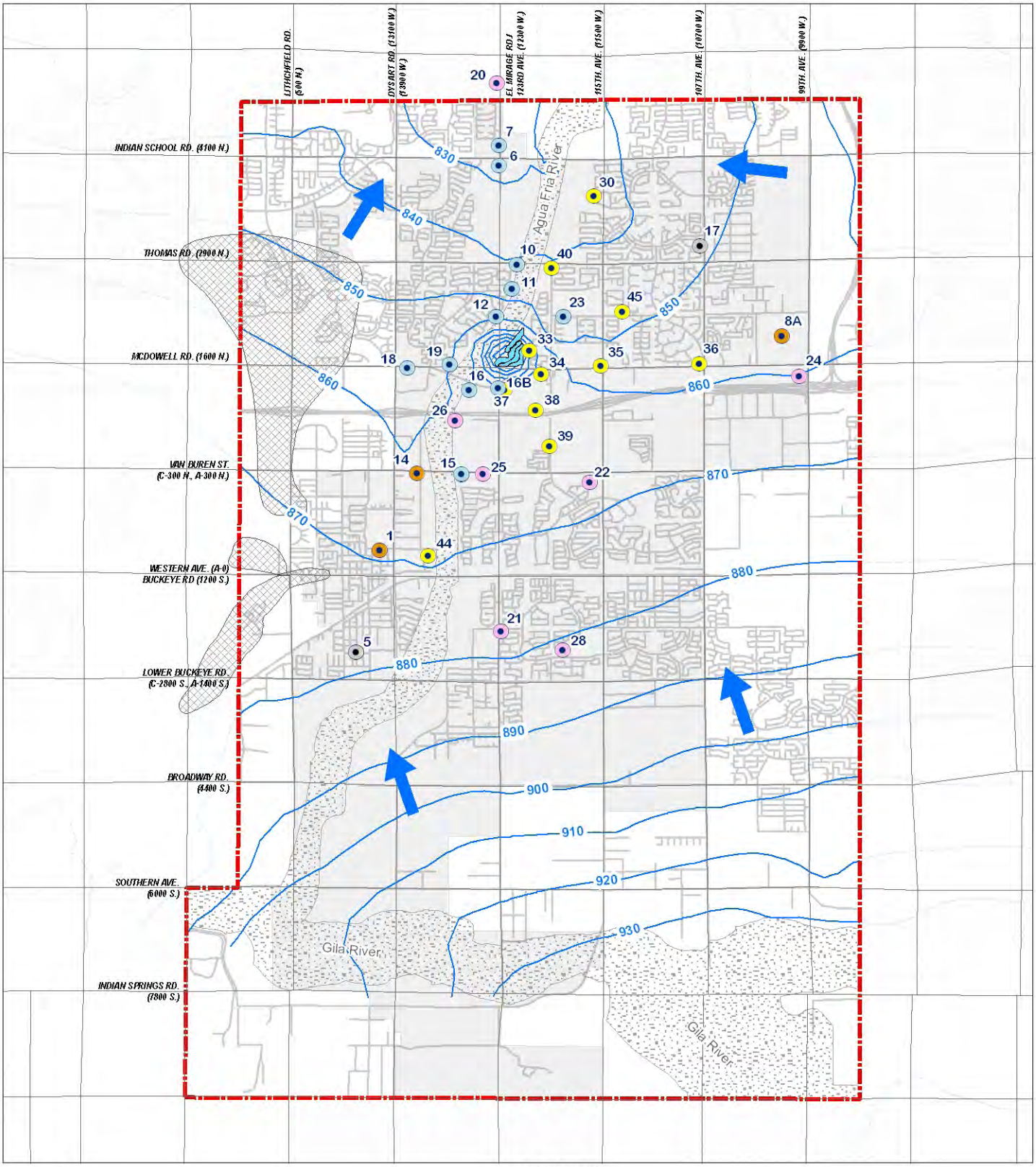
CITY OF AVONDALE, ARIZONA
WATER RESOURCE MASTER PLAN

ALTERNATIVE 1
2050 SIMULATED POTENTIOMETRIC SURFACE MAP

MALCOLM PIRNIE

MAY 2010

FIGURE 43



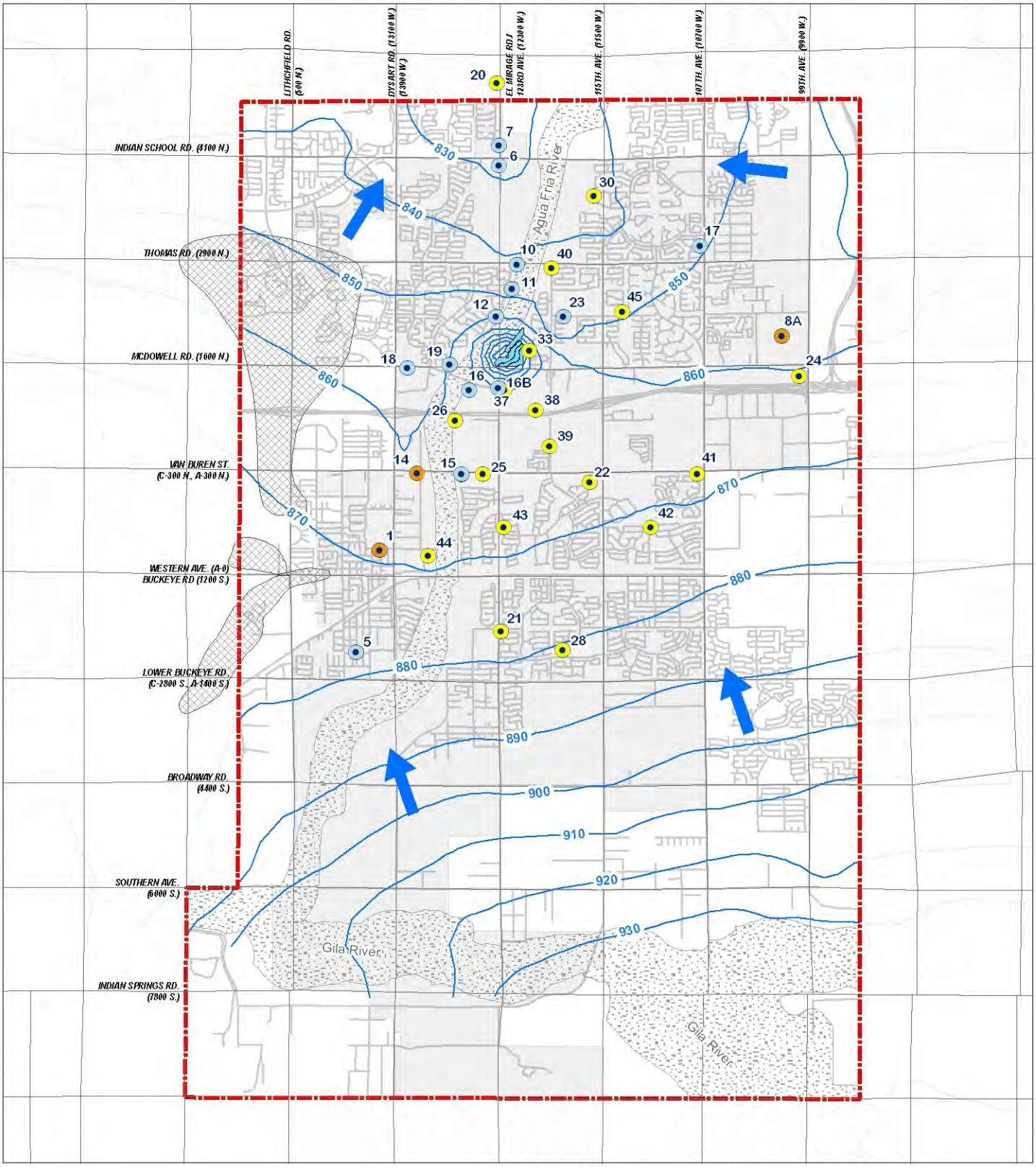
CITY OF AVONDALE, ARIZONA
WATER RESOURCE MASTER PLAN

ALTERNATIVE 2
2050 SIMULATED POTENTIOMETRIC SURFACE MAP

MALCOLM PIRNIE

MAY 2010

FIGURE 44



Explanation

- Existing Well
- Planned Well
- Proposed for Redevelopment
- Proposed New Well
- Inactive
- Study Area
- City of Avondale Sevice Area
- Avondale Recharge Facility
- Contaminant Plumes
- Potentiometric Surface Contour (c.i. = 10 feet)

N

0 1,750 3,500 7,000
Feet

City of Avondale

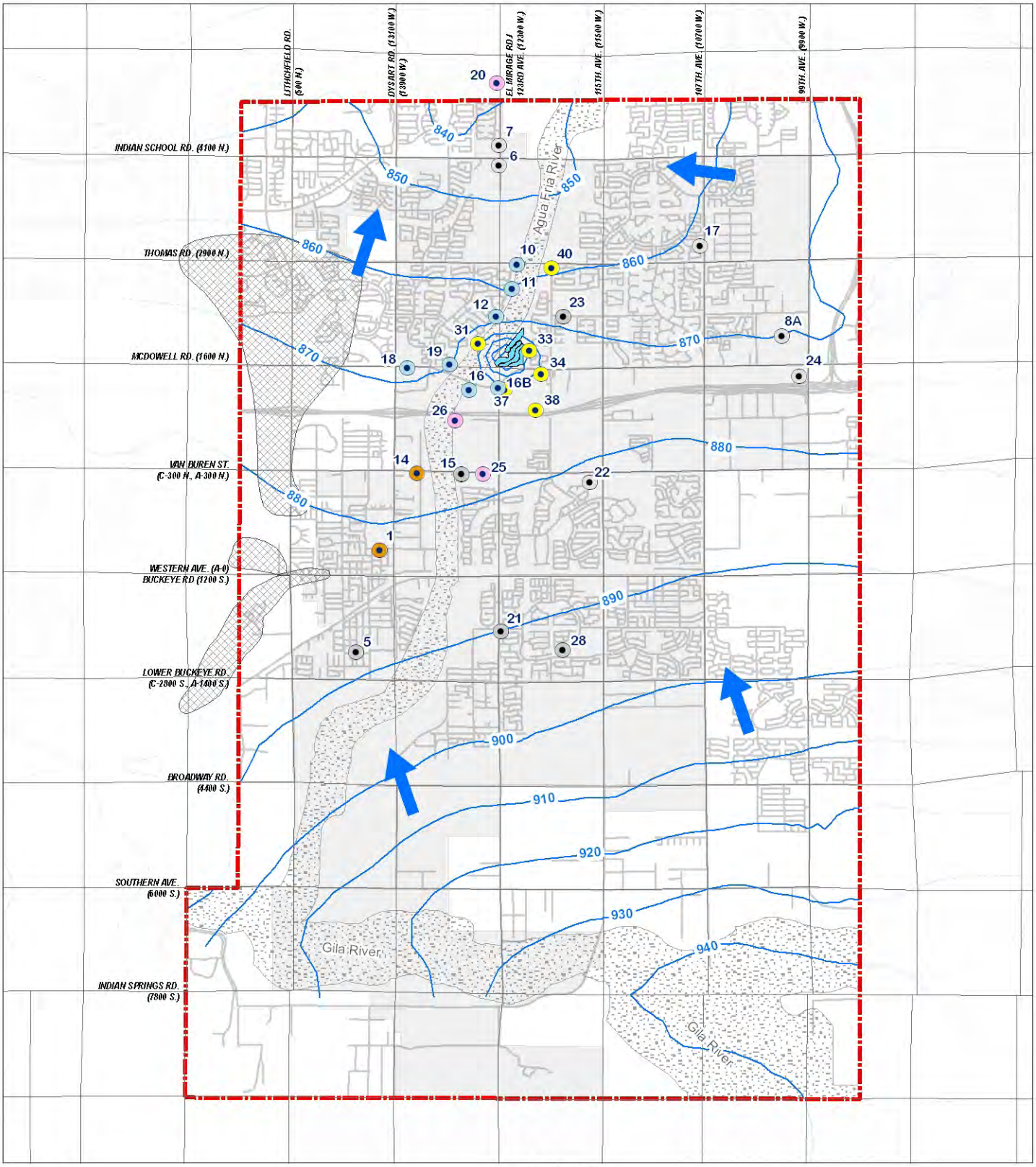
CITY OF AVONDALE, ARIZONA
WATER RESOURCE MASTER PLAN

ALTERNATIVE 3
2050 SIMULATED POTENTIOMETRIC SURFACE MAP

MALCOLM PIRNIE

MAY 2010

FIGURE 45



CITY OF AVONDALE, ARIZONA
WATER RESOURCE MASTER PLAN

ALTERNATIVES 4 AND 5
2050 SIMULATED POTENTIOMETRIC SURFACE MAP

MALCOLM PIRNIE

MAY 2010

FIGURE 46

THIS PAGE INTENTIONALLY LEFT BLANK

A: Digital Groundwater Flow Modeling Files

THIS PAGE INTENTIONALLY LEFT BLANK

B: Model Water Budgets

APPENIDIX TABLE B-1

SIMULATED WATER BUDGETS - MODEL BOUNDARIES

Stress Period	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	Total
Boundary 1 - Border with Lake Pleasant Subbasin - Agua Fria River Valley.																									
ADWR Model - Inflow to WSRV subbasin (acre-feet)	8,341	7,890	7,444	7,409	7,436	7,443	7,445	7,451	7,453	7,422	8,924	8,666	8,158	7,860	7,620	7,473	7,346	7,240	7,962	14,096	13,197	13,697	12,481	11,695	*212,151*
Refined Model - Inflow from boundary cells (acre-feet)	7,126	7,850	7,448	7,450	7,513	7,535	7,557	7,585	7,588	7,560	7,946	8,607	8,171	7,942	7,718	7,584	7,465	7,365	8,013	14,039	13,617	14,008	13,087	12,474	*213,249*
Percent Change																									*100.5%*
Boundary 2 - Border with Lake Pleasant Subbasin - New River Valley.																									
ADWR Model - Inflow to WSRV subbasin (acre-feet)	967	1,069	1,116	1,148	1,188	1,194	1,196	1,195	1,192	1,187	1,182	1,185	1,193	1,197	1,194	1,187	1,177	1,166	1,155	1,151	1,170	1,202	1,237	1,265	*28,114*
Refined Model - Inflow from boundary cells (acre-feet)	943	1,059	1,111	1,144	1,186	1,193	1,195	1,194	1,191	1,186	1,181	1,183	1,191	1,196	1,194	1,186	1,176	1,165	1,153	1,150	1,168	1,200	1,235	1,263	*28,042*
Percent change																									*99.7%*
Boundary 3 - Border with Lake Pleasant Subbasin - Skunk Creek Valley.																									
ADWR Model - Inflow to WSRV subbasin (acre-feet)	1,288	1,384	1,497	1,558	1,608	1,650	1,684	1,712	1,735	1,754	1,770	1,782	1,792	1,800	1,806	1,810	1,813	1,816	1,818	1,819	1,822	1,823	1,821	1,818	*41,180*
Refined Model - Inflow from boundary cells (acre-feet)	1,314	1,442	1,529	1,585	1,632	1,671	1,704	1,731	1,753	1,771	1,786	1,798	1,807	1,814	1,821	1,817	1,821	1,824	1,826	1,828	1,841	1,840	1,836	1,832	*41,624*
Percent change																									*101.1%*
Boundary 4 - Border with East Salt River Valley Subbasin.																									
ADWR Model - Inflow to WSRV subbasin (acre-feet)	893	1,378	1,064	1,673	1,115	2,566	2,961	3,230	3,312	2,219	2,465	2,414	2,000	2,417	2,427	2,625	2,627	2,645	2,596	2,533	2,509	2,662	3,563	3,242	*57,139*
Refined Model - Inflow from boundary cells (acre-feet)	765	1,253	1,137	2,000	2,532	2,799	3,052	3,242	3,346	2,654	2,811	2,391	2,139	2,270	2,309	2,509	2,516	2,547	2,500	2,440	2,419	2,489	3,089	3,132	*58,342*
Percent change (inflow)																									*102.1%*
ADWR Model - Outflow from WSRV subbasin (acre-feet)	149	25	59	81	67	43	23	16	12	0	0	0	0	8	0	0	0	0	0	0	0	0	0	0	*484*
Refined Model - Outflow to boundary cells (acre-feet)	918	32	75	90	70	44	25	19	17	2	0	2	0	0	5	0	0	0	0	0	0	0	0	0	*1,299*
Percent change (outflow)																									*268.5%*
Boundary 5 - Border with Maricopa-Stanfield Subbasin																									
ADWR Model - Inflow to WSRV subbasin (acre-feet)	3,545	5,769	5,516	5,241	4,591	4,610	4,790	5,117	5,334	4,605	5,603	6,341	6,312	5,948	5,813	6,032	6,918	7,044	7,323	7,452	6,652	6,398	6,126	6,031	*139,111*
Refined Model - Inflow from boundary cells (acre-feet)	3,616	6,867	6,194	5,724	4,803	4,808	4,965	5,287	5,451	4,553	5,884	4,100	6,185	5,797	5,657	5,879	6,918	6,943	7,249	7,335	6,284	6,093	5,824	5,779	*138,197*
Percent change (inflow)																									*99.3%*
ADWR Model - Outflow from WSRV subbasin (acre-feet)	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*
Refined Model - Outflow to boundary cells (acre-feet)	485	151	125	115	110	75	46	18	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	*1,123*
Percent change (outflow)																									*NA*
Boundary 6 - Border with Hassayampa Subbasin - Southern Hassayampa River Valley																									
ADWR Model - Inflow from boundary cells (acre-feet)	11,636	12,751	13,045	13,845	13,650	14,506	15,129	14,968	13,458	12,198	11,658	11,247	11,185	11,847	10,821	11,702	11,294	10,814	10,729	10,777	10,405	9,091	5,567	6,380	*11,613*
Refined Model - Inflow from boundary cells (acre-feet)	10,752	12,083	12,444	13,275	13,086	13,937	14,507	14,352	12,829	11,684	11,179	10,773	10,743	11,434	10,444	11,272	10,878	10,363	10,260	10,282	9,995	8,796	5,522	6,425	*11,138*
Percent change (inflow)																									*95.9%*
ADWR Model - Outflow from boundary cells (acre-feet)	2,442	3,050	3,309	3,429	3,525	3,419	3,458	3,527	3,593	3,690	3,843	3,985	4,060	4,118	4,136	4,165	4,256	4,328	4,372	4,335	3,570	3,588	7,313	4,488	*3,917*
Refined model - Outflow from boundary cells (acre-feet)	2,303	2,896	3,150	3,270	3,367	3,262	3,300	3,369	3,438	3,540	3,697	3,842	3,921	3,983	4,004	4,034	4,120	4,182	4,220	4,186	3,339	3,350	7,598	4,289	*3,777*
Percent change (outflow)																									*96.4%*
Boundary 7 - Border with Hassayampa Subbasin - Gila River Valley																									
ADWR Model - Outflow from boundary cells (acre-feet)	3,308	2,914	2,782	3,172	3,207	3,178	3,204	3,176	3,218	3,329	3,304	3,259	3,258	3,256	3,231	3,140	3,211	3,036	3,163	2,778	3,169	3,224	3,309	3,559	*3,183*
Refined Model - Outflow from boundary cells (acre-feet)	3,541	3,207	3,091	3,474	3,504	3,477	3,505	3,479	3,522	3,600	3,575	3,528	3,531	3,531	3,510	3,427	3,495	3,322	3,448	3,078	3,467	3,522	3,591	3,823	*3,469*
Percent change																									*109.0%*

APPENDIX TABLE B-2

SIMULATED WATER BUDGETS - ENTIRE MODEL DOMAIN

Stress Per	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	*Total*
ADWR Flow Budgets for Refined Model Area																									
Inflows (acre-feet)																									
Storage	73,120	212,063	70,582	112,369	87,568	93,767	127,562	181,726	66,449	21,439	13,321	111,892	53,491	115,067	117,901	36,928	129,247	138,644	113,381	184,513	111,789	87,705	16,598	34,316	*2,311,438*
Streams	90,984	73,171	77,945	68,736	71,957	72,280	71,636	71,913	72,759	78,939	98,506	87,381	94,122	86,062	88,766	86,746	88,880	92,957	93,058	110,731	107,989	112,748	111,998	103,352	*2,113,615*
Wells	3,368	3,368	3,368	3,368	3,368	3,368	3,368	3,368	3,368	3,368	3,368	3,368	3,368	3,368	3,368	3,368	3,368	3,368	3,368	3,368	3,368	3,368	3,368	3,368	*80,830*
Recharge	702,331	457,994	515,125	436,230	428,484	442,872	405,772	405,886	413,083	496,771	573,213	403,350	425,712	389,901	374,304	363,760	355,133	351,393	344,848	338,830	461,823	449,435	459,595	444,423	*10,440,269*
Outflows (acre-feet)																									
Storage	457,495	70,669	88,189	49,852	63,693	50,600	37,757	28,736	50,347	194,215	234,382	44,903	54,277	23,342	28,164	55,048	21,214	22,375	15,317	27,518	111,668	105,890	142,475	113,682	*2,091,807*
Const Head	5,761	5,976	6,103	6,614	6,746	6,611	6,675	6,716	6,825	7,033	7,161	7,260	7,333	7,390	7,383	7,320	7,482	7,380	7,550	7,128	6,753	6,826	10,644	8,063	*170,734*
Streams	27,770	4,433	8,885	3,829	3,675	3,367	2,641	2,305	2,240	4,666	7,204	2,987	3,107	3,111	2,981	3,356	3,719	2,965	2,862	3,124	4,407	6,390	11,201	13,686	*134,910*
Wells	355,580	648,094	545,414	550,432	507,455	545,759	561,189	628,070	497,051	385,340	423,017	550,523	509,785	565,580	550,905	426,967	551,707	562,768	542,834	624,007	579,768	553,474	443,054	463,921	*12,572,696*
Evapotranspiration	50,766	45,302	47,773	42,487	40,468	38,800	37,036	34,841	32,449	36,847	41,564	35,022	38,993	35,270	33,788	35,657	34,249	32,052	30,936	29,336	29,368	30,407	32,697	34,238	*880,343*

Refined Model Total Flow Budgets																										***% Change from ADWR Model***
Inflows (acre-feet)																										
Storage	72,870	205,292	67,261	110,703	85,445	91,782	126,622	179,727	63,029	21,222	13,012	107,914	50,808	113,201	115,073	36,066	127,315	137,133	111,059	182,423	111,018	88,936	16,768	34,953	*2,269,632*	*98.2%*
Streams	102,996	87,037	92,636	81,625	83,130	83,425	82,592	82,407	83,288	90,141	106,270	106,736	106,394	97,563	101,481	97,731	100,671	105,188	105,621	123,203	118,706	120,252	119,732	111,578	*2,390,405*	*113.1%*
Wells	3,368	3,368	3,368	3,368	3,368	3,368	3,368	3,368	3,368	3,368	3,368	3,368	3,368	3,368	3,368	3,368	3,368	3,368	3,368	3,368	3,368	3,368	3,368	3,368	*80,830*	*100.0%*
Recharge	702,412	460,259	518,549	440,492	434,638	450,083	412,095	412,149	420,428	505,422	585,646	415,800	438,564	402,911	387,019	377,497	369,427	365,669	358,358	352,562	487,211	476,076	486,234	474,922	*10,734,422*	*102.8%*
Outflows (acre-feet)																										
Storage	465,753	80,165	99,277	58,423	72,690	59,310	42,894	32,093	56,975	209,385	253,350	56,939	62,286	28,448	33,394	63,779	26,936	28,412	17,945	27,710	127,661	119,309	151,822	128,120	*2,303,076*	*110.1%*
Const Head	7,260	6,299	6,454	6,963	7,066	6,872	6,889	6,898	6,991	7,189	7,319	9,375	7,471	7,543	7,534	7,477	7,630	7,519	7,683	7,279	6,820	6,885	11,212	8,128	*178,759*	*104.7%*
Streams	24,093	2,447	7,140	2,819	2,872	2,869	2,549	2,406	2,419	4,241	6,836	2,395	2,405	2,418	2,338	2,631	2,744	2,442	2,297	2,465	3,875	4,900	9,193	12,390	*113,186*	*83.9%*
Wells	355,572	648,293	545,982	550,828	507,995	546,350	561,754	628,321	497,058	385,430	423,206	550,728	509,940	565,584	550,904	427,081	551,821	562,896	542,523	624,051	580,084	553,788	443,544	464,284	*12,578,015*	*100.0%*
Evpapotranspiration	53,470	49,157	52,676	48,215	46,632	45,147	43,536	41,362	38,862	43,344	48,401	43,260	47,297	43,535	41,958	43,971	42,457	40,328	39,010	37,167	37,245	38,213	40,956	42,854	*1,049,054*	*119.2%*

APPENDIX TABLE B-3

COMPLETE SIMULATED WATER BUDGET - REFINED GROUNDWATER FLOW MODEL

Stress Per	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
Inflows (acre-feet)																								
Storage	72,870	205,292	67,261	110,703	85,445	91,782	126,622	179,727	63,029	21,222	13,012	107,914	50,808	113,201	115,073	36,066	127,315	137,133	111,059	182,423	111,018	88,936	16,768	34,953
Const Head	24,509	30,410	29,704	31,068	30,681	31,896	32,951	33,435	32,199	29,442	30,824	28,886	30,274	30,492	29,177	30,285	30,812	30,245	31,041	37,124	35,371	34,473	30,632	30,944
Streams	102,996	87,037	92,636	81,625	83,130	83,425	82,592	82,407	83,288	90,141	106,270	106,736	106,394	97,563	101,481	97,731	100,671	105,188	105,621	123,203	118,706	120,252	119,732	111,578
Wells	3,368	3,368	3,368	3,368	3,368	3,368	3,368	3,368	3,368	3,368	3,368	3,368	3,368	3,368	3,368	3,368	3,368	3,368	3,368	3,368	3,368	3,368	3,368	3,368
Recharge	702,412	460,259	518,549	440,492	434,638	450,083	412,095	412,149	420,428	505,422	585,646	415,800	438,564	402,911	387,019	377,497	369,427	365,669	358,358	352,562	487,211	476,076	486,234	474,922
Evpt.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Total	906,155	786,367	711,518	667,255	637,263	660,554	657,629	711,086	602,312	649,596	739,120	662,704	629,408	647,534	636,118	54,761	631,594	641,603	609,447	698,680	755,674	723,105	656,734	655,765
Outflows (acre-feet)																								
Storage	465,753	80,165	99,277	58,423	72,690	59,310	42,894	32,093	56,975	209,385	253,350	56,939	62,286	28,448	33,394	63,779	26,936	28,412	17,945	27,710	127,661	119,309	151,822	128,120
Const Head	7,260	6,299	6,454	6,963	7,066	6,872	6,889	6,898	6,991	7,189	7,319	9,375	7,471	7,543	7,534	7,477	7,630	7,519	7,683	7,279	6,820	6,885	11,212	8,128
Streams	24,093	2,447	7,140	2,819	2,872	2,869	2,549	2,406	2,419	4,241	6,836	2,395	2,405	2,418	2,338	2,631	2,744	2,442	2,297	2,465	3,875	4,900	9,193	12,390
Wells	355,572	648,293	545,982	550,828	507,995	546,350	561,754	628,321	497,058	385,430	423,206	550,728	509,940	565,584	550,904	427,081	551,821	562,896	542,523	624,051	580,084	553,788	443,544	464,284
Recharge	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Evpt.	53,470	49,157	52,676	48,215	46,632	45,147	43,536	41,362	38,862	43,344	48,401	43,260	47,297	43,535	41,958	43,971	42,457	40,328	39,010	37,167	37,245	38,213	40,956	42,854
Total	906,148	786,360	711,529	667,248	637,256	660,549	657,622	711,080	602,306	649,589	739,112	662,697	629,400	647,528	636,129	544,940	631,588	641,597	609,458	698,672	755,685	723,095	656,726	655,776
Percent Discrepancy	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*89.95%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*

C: Model Residual Summary

APPENDIX TABLE C-1

ADWR MODEL UNWEIGHTED CALIBRATION RESIDUALS - WSRV SUBBASIN

2002/2003 Calibration Data (WSRV Subbasin)

Local ID	Measured Elevations (ft-amsl)	Simulated Elevations (ft-amsl)	Unweighted Residual (feet)
A-01-01 02CCC	907	899	-8.1
A-01-01 03BBB	889	887	-2.5
A-01-01 06CBB1	901	883	-17.7
A-01-01 07CCD	911	893	-18.1
A-01-01 09BBB2	899	893	-6.1
A-01-01 10CCC2	919	903	-15.7
A-01-01 11ACB	923	904	-19.4
A-01-01 11ADD	920	907	-12.6
A-01-01 11CBC	920	905	-14.9
A-01-01 12BBB	921	904	-16.6
A-01-01 12DBA2	932	910	-22.1
A-01-01 13ADA	933	916	-17.1
A-01-01 14BAB1	930	910	-19.6
A-01-01 14BAB2	926	909	-17.2
A-01-01 15AAA	923	909	-14.4
A-01-01 16AAA	912	903	-9.4
A-01-01 17DAA	927	905	-22
A-01-01 19ABB	924	904	-20.4
A-01-01 19DCD1	926	912	-13.7
A-01-01 21AAA	911	913	2.2
A-01-01 21DDA2	934	923	-10.9
A-01-01 21DDA3	923	923	0.5
A-01-01 22CDA	926	925	-0.8
A-01-01 23AAB	931	920	-11.1
A-01-01 23DBA2	934	926	-8.2
A-01-01 23DDA	939	930	-9.3
A-01-01 24AAA	939	925	-14.3
A-01-01 26AAA	947	934	-12.5
A-01-01 28CAC	937	929	-7.6
A-01-01 30AAC1	924	915	-9.2
A-01-01 30AAC2	909	915	5.9
A-01-01 30BAA1	907	910	3.2
A-01-01 35CCC	948	948	0.4
A-01-01S25BAB	948	947	-0.8
A-01-01S25BBA	946	947	1.1
A-01-01S26CAA	943	941	-1.5
A-01-02 01CAC	968	940	-28.5
A-01-02 07BBB	925	909	-15.7
A-01-02 07CCC2	931	914	-17.4
A-01-02 08BAA1	932	916	-16.3
A-01-02 08BBB	929	913	-15.7
A-01-02 09AAB2	936	923	-13.5
A-01-02 09BBB	934	919	-15.1
A-01-02 09CBC	931	919	-12.3
A-01-02 09CDB	959	922	-37.2
A-01-02 09DDD	959	925	-33.9
A-01-02 10CBC	940	922	-18.4
A-01-02 11AAA	956	934	-22.3
A-01-02 11BAB	952	931	-21.3
A-01-02 11CBC2	952	928	-24.1
A-01-02 12BAA	964	941	-22.8
A-01-02 12CBC	956	931	-24.9
A-01-02 14AAD	957	931	-26.1
A-01-02 14BBC	949	925	-23.7
A-01-02 14CCB	954	929	-25
A-01-02 14CDD	958	931	-26.8
A-01-02 15ACC	947	926	-21.1
A-01-02 15BCC2	943	926	-17.5
A-01-02 16DBB2	940	925	-15
A-01-02 17ADD	942	923	-18.6
A-01-02 17CAA	937	922	-14.8
A-01-02 18ACB	934	917	-17.2
A-01-02 18DDD2	938	926	-11.6
A-01-02 26AAA	976	950	-25.9
A-01-02 26DDD	985	963	-22
A-01-02 29BBB	949	942	-6.7
A-01-02 32AAA2	964	947	-17.1
A-01-02 32CCD	961	948	-13
A-01-02 33CBD	967	952	-14.8
A-01-02 35DDD	986	973	-13.3
A-01-02N29DDA	966	948	-17.9
A-01-03 01ADA2	1089	1075	-14.1
A-01-03 01DDD	1076	1073	-3.3
A-01-03 05BAA	993	975	-18.1
A-01-03 08ABB1	988	973	-15.2
A-01-03 08BDA2	983	971	-11.8
A-01-03 08CDD	986	971	-14.8
A-01-03 18BBC	968	943	-25.2
A-01-03 31DDA	999	986	-12.9
A-01-03 33ADB	1010	1025	15.4
A-01-03 35ADD	1058	1074	16.3
A-01-03 36BCC	1046	1076	30.2
A-01-04 19ACC	1066	1082	15.5
A-01-04 30BAB	1077	1082	4.8
A-01-04 30BDD	1080	1085	4.7
A-01-04 30CDD	1081	1086	4.7
A-02-01 01DDA	892	906	13.7
A-02-01 04CBB2	903	874	-28.7
A-02-01 08CAA	880	867	-12.6
A-02-01 08CDD2	872	864	-7.8
A-02-01 08DDD	874	869	-4.8
A-02-01 09CBB2	890	869	-21.2
A-02-01 09DDD2	901	876	-24.6
A-02-01 11DDD2	910	891	-19.3
A-02-01 13CCC2	892	890	-1.8
A-02-01 14ACC	894	882	-12.5
A-02-01 14BBA	895	882	-13
A-02-01 14CCC	892	880	-11.6
A-02-01 15CBB	899	876	-23.1
A-02-01 17CAB2	871	862	-9
A-02-01 17DDD2	879	872	-6.9
A-02-01 20BBB	869	862	-7.3
A-02-01 20BCC2	869	864	-4.8
A-02-01 20CAC	869	865	-3.7
A-02-01 20CCC2	866	867	1
A-02-01 20DAA	877	871	-5.8
A-02-01 20DCC	867	869	1.7
A-02-01 20DDD2	871	872	0.9
A-02-01 28AAA1	885	879	-5.5
A-02-01 29CAA2	868	872	3.5
A-02-01 29DDD2	878	876	-1.5
A-02-01 30CAA2	864	867	3
A-02-01 30CBB	864	869	5.3
A-02-01 30DAA2	862	868	6

1997/1998 Calibration Data (WSRV Subbasin)

Local ID	Measured Elevations (ft-amsl)	Simulated Elevations (ft-amsl)	Unweighted Residual (feet)
A-01-01 02BBB2	934	918	-16
A-01-01 02CCC	935	920	-15.2
A-01-01 03ABB2	924	915	-8.9
A-01-01 03BBB	921	912	-9.5
A-01-01 03BDB	923	914	-9.4
A-01-01 04AAA2	926	912	-13.9
A-01-01 04BAC	909	908	-0.8
A-01-01 04CAB	908	909	1
A-01-01 06CBB1	913	895	-18
A-01-01 07CCD	921	904	-17.2
A-01-01 09AAA	925	916	-9.3
A-01-01 09BAC	918	913	-4.9
A-01-01 09BBB2	925	911	-14.1
A-01-01 10AAA2	931	920	-10.8
A-01-01 10CCC2	938	921	-16.5
A-01-01 11ACB	945	923	-21.8
A-01-01 11ADD	939	926	-13.3
A-01-01 11CBC	933	924	-9.2
A-01-01 12BBB	948	925	-23.3
A-01-01 12DBA2	951	928	-22.7
A-01-01 13ADA	951	933	-18.3
A-01-01 14BAB1	946	927	-18.7
A-01-01 14BAB2	940	927	-12.9
A-01-01 14DDA	936	935	-0.8
A-01-01 15AAA	938	926	-11.9
A-01-01 16AAA	932	921	-10.6
A-01-01 17BBB	932	912	-20.3
A-01-01 17DAA	938	921	-17.3
A-01-01 19ABB	931	913	-17.8
A-01-01 19DCD1	932	919	-12.8
A-01-01 21AAA	921	929	8.1
A-01-01 21DDA2	939	935	-3.7
A-01-01 21DDA3	940	935	-4.8
A-01-01 22CDA	936	938	2.2
A-01-01 23AAB	943	935	-7.6
A-01-01 23DBA2	947	940	-6.7
A-01-01 23DDA	951	944	-7.1
A-01-01 24AAA	953	940	-12.9
A-01-01 26AAA	949	948	-1.5
A-01-01 28BCB	935	933	-2.4
A-01-01 30AAC1	928	920	-7.6
A-01-01 30AAC2	932	921	-10.6
A-01-01 30BAA1	928	917	-11.3
A-01-01 33AAD	939	945	6.4
A-01-01 35DDC	951	958	6.8
A-01-01 36AAD	957	957	0.5
A-01-01 36DDA	965	958	-7.3
A-01-01S25BAB	959	958	-1.1
A-01-01S25BBA	954	952	-1.7
A-01-01S26CAA	952	952	0.3
A-01-02 01AAB1	1021	968	-53.5
A-01-02 01CAC	983	956	-26.9
A-01-02 02BCC	966	949	-17.4
A-01-02 07BBB	948	929	-18.9
A-01-02 07CCC2	947	931	-16.1
A-01-02 07DCD	945	935	-9.7
A-01-02 08BAA1	952	934	-17.7
A-01-02 08BBB	945	932	-12.5
A-01-02 09AAB2	957	940	-16.9
A-01-02 09BBB	954	937	-17.2
A-01-02 09CBC	949	936	-12.9
A-01-02 09CCC	953	936	-17.1
A-01-02 09DAC	984	942	-41.7
A-01-02 09DCC	1001	941	-59.5
A-01-02 09DDD	992	943	-48.8
A-01-02 10ABA	963	944	-19.2
A-01-02 10CBC	956	939	-17.4
A-01-02 11AAA	977	948	-28.7
A-01-02 11BAB	972	946	-25.7
A-01-02 11CBC2	970	946	-24.3
A-01-02 12BAA	983	958	-25.5
A-01-02 12CBC	974	949	-24.9
A-01-02 13ABD2	985	960	-25.3
A-01-02 13CDD2	981	960	-20.6
A-01-02 13DAD	989	966	-23.1
A-01-02 14AAD	975	951	-23.9
A-01-02 14BBC	966	943	-22.9
A-01-02 14CCB	969	948	-20.9
A-01-02 14CDD	974	951	-22.9
A-01-02 15ACC	960	943	-17.1
A-01-02 15BCC2	958	941	-16.9
A-01-02 16DBB2	956	941	-15.1
A-01-02 17ADD	956	940	-15.8
A-01-02 17CAA	952	939	-13.1
A-01-02 18ACB	949	934	-14.8
A-01-02 18DDD2	950	943	-7.5
A-01-02 19BAA	955	943	-12
A-01-02 19CAD	956	951	-5.3
A-01-02 19DDA	952	951	-0.8
A-01-02 24BBB2	981	956	-25.2
A-01-02 24DAB	994	971	-23
A-01-02 24DDC2	999	976	-22.5
A-01-02 26DDD	999	982	-16.5
A-01-02 29BBB	960	957	-3.1
A-01-02 31AAA	964	959	-5.5
A-01-02 32AAA2	977	960	-17
A-01-02 32BAA	974	959	-14.6
A-01-02 32CCD	966	960	-6.5
A-01-02 32DDD	990	965	-25.1
A-01-02 33CBD	978	964	-13.7
A-01-02 35DDD	1002	996	-6
A-01-02N22DAB	993	961	-32
A-01-02N29DDA	975	962	-13.3
A-01-03 01ADA2	1097	1091	-6.4
A-01-03 01DDD	1086	1091	4.6
A-01-03 02AAB	1060	1058	-1.9
A-01-03 05BAA	1011	991	-20.1
A-01-03 06DCD	999	978	-21.3
A-01-03 08ABB1	1011	991	-20.4
A-01-03 08BDA2	1000	989	-11
A-01-03 08CDD	1004	991	-13.3
A-01-03 09ADA	1020	1018	-1.5
A-01-03 16CCB	1006	1003	-3
A-01-03 18BBB2	989	964	-25.4

1991/1992 Calibration Data (WSRV Subbasin)

Local ID	Measured Elevations (ft-amsl)	Simulated Elevations (ft-amsl)	Unweighted Residual (feet)
A-01-01 02BBB2	936	929	-6.9
A-01-01 02CCC	931	932	1.1
A-01-01 03ABB2	919	926	7.1
A-01-01 03BBB	924	923	-1.4
A-01-01 03BDB	929	925	-4.0
A-01-01 04AAA2	927	923	-3.8
A-01-01 06CBB1	928	905	-22.8
A-01-01 06CBB2	918	906	-12.1
A-01-01 06CDD	925	911	-13.9
A-01-01 06DAA	918	915	-2.7
A-01-01 07CCD	925	913	-11.6
A-01-01 08BAA	926	922	-4.1
A-01-01 08CAB	938	923	-15.3
A-01-01 09BAC	930	926	-3.7
A-01-01 09BBB2	927	924	-2.7
A-01-01 09DAD	938	932	-5.5
A-01-01 10AAA1	939	932	-6.6
A-01-01 10CCC2	943	934	-8.9
A-01-01 11ACB	949	935	-13.6
A-01-01 11ADD	947	937	-9.5
A-01-01 11CBC	941	936	-4.9
A-01-01 12BBB	950	937	-13.4
A-01-01 12DBA2	958	939	-19.1
A-01-01 13ADA	958	944	-13.8
A-01-01 14BAB1	952	938	-13.7
A-01-01 14BAB2	947	939	-8.1
A-01-01 14DAB	952	943	-9.2
A-01-01 14DDA	953	946	-6.8
A-01-01 15AAA	944	937	-6.8
A-01-01 15DAA	947	941	-5.6
A-01-01 16AAA	928	934	6.1
A-01-01 17BBB	935	923	-11.8
A-01-01 18ACB	924	918	-6.0
A-01-01 19ABB	935	921	-14.1
A-01-01 19ACB2	913	919	6.4
A-01-01 19CCC	932	917	-14.9
A-01-01 19CCD	930	919	-11.2
A-01-01 19DCD1	936	924	-11.7
A-01-01 21DDA3	946	943	-2.8
A-01-01 22CDA	942	946	4.3
A-01-01 23AAB	968	946	-21.9
A-01-01 23DBA2	953	949	-3.5
A-01-01 23DDA	957	952	-5.1
A-01-01 24AAA	960	949	-10.8
A-01-01 28CAC	944	939	-5.2
A-01-01 29DAA1	940	939	-1.3
A-01-01 29DAA2	940	939	-1.3
A-01-01 29DCD	941	938	-2.7
A-01-01 30AAC1	933	925	-8.1
A-01-01 30AAC2	926	926	0.4
A-01-01 30BAA1	922	921	-0.8
A-01-01 30BAA2	931	921	-9.6
A-01-01 35DDC	953	958	5.0
A-01-01 36AAD	962	960	-1.5
A-01-01 36DDA	970	961	-8.5
A-01-01N25BBB2	950	952	2.3
A-01-01S25BAB	966	959	-6.8
A-01-01S25BBA	960	956	-4.4
A-01-01S26CAA	959	955	-4.2
A-01-02 01CAC	983	963	-20.0
A-01-02 02BCC	972	956	-15.9
A-01-02 07BBB	953	939	-14.2
A-01-02 07CCC2	954	942	-12.3
A-01-02 08BAA1	958	942	-15.5
A-01-02 08BBB	956	941	-14.8
A-01-02 08DAA	961	944	-16.7
A-01-02 09AAB2	962	948	-14.5
A-01-02 09BBB	960	945	-15.4
A-01-02 09CBC	957	945	-11.9
A-01-02 09CDB	980	948	-31.6
A-01-02 09DAC	988	950	-37.6
A-01-02 09DCC	981	950	-31.3
A-01-02 09DDD	988	951	-36.8
A-01-02 10ABA	967	952	-15.2
A-01-02 10CCB	965	947	-17.8
A-01-02 11AAA	978	958	-19.7
A-01-02 11BAB	975	955	-19.7
A-01-02 11CBC2	976	954	-22.2
A-01-02 12BAA	983	964	-18.6
A-01-02 12CBC	977	958	-19.1
A-01-02 13ABD2	986	963	-22.9
A-01-02 13CDD2	985	968	-16.6
A-01-02 13DAD	996	971	-25.5
A-01-02 14AAD	977	958	-18.7
A-01-02 14BBC	972	952	-20.1
A-01-02 14CCB	975	955	-19.6
A-01-02 14CDD	977	958	-18.5
A-01-02 15ACC	969	952	-17.5
A-01-02 15BCC2	967	950	-17.0
A-01-02 16CCC1	968	952	-15.6
A-01-02 16DBB2	965	950	-15.5
A-01-02 17ADD	965	949	-16.2
A-01-02 17CAA	961	948	-13.0
A-01-02 18ACB	958	944	-13.7
A-01-02 18DDD2	924	951	26.8
A-01-02 19BAA	966	951	-14.9
A-01-02 19CAD	963	956	-6.5
A-01-02 19DDA	966	957	-9.1
A-01-02 24BBB2	985	963	-21.9
A-01-02 24DAB	988	981	-6.5
A-01-02 24DDC2	988	987	-1.0
A-01-02 26AAA	992	980	-11.8
A-01-02 26DDD	998	996	-2.0
A-01-02 29BBB	967	961	-6.2
A-01-02 31AAA	964	962	-1.9
A-01-02 32AAA2	978	965	-12.9
A-01-02 32BAA	977	964	-13.2
A-01-02 32DDD	981	974	-7.3
A-01-02 33CBD	979	972	-6.7
A-01-02 35BAB1	994	989	-4.9
A-01-02 35DDD	1034	1014	-20.0
A-01-02N22DAB	985	967	-18.4
A-01-02N29DDA	980	967	-13.4
A-01-03 01ADA2	1105	1089	-16.3

APPENDIX TABLE C-1

ADWR MODEL UNWEIGHTED CALIBRATION RESIDUALS - WSRV SUBBASIN

A-02-01 30DDD2	871	872	0.5
A-02-01 32DAB2	880	878	-2.4
A-02-01 32DDA	895	879	-15.8
A-02-01 33ACC	882	880	-1.9
A-02-01 33CCC	881	882	0.8
A-02-01 33CDD2	887	883	-3.6
A-02-01 34BBB2	882	881	-0.7
A-02-01 34BCC2	886	882	-3.5
A-02-01 35DDD	906	899	-7.1
A-02-01 36DAD	912	903	-8.6
A-02-02 02ABC	994	955	-39.3
A-02-02 04CAB	946	911	-35
A-02-02 08BBC2	932	912	-19.9
A-02-02 09ADD2	954	931	-23.2
A-02-02 12ACB	1044	983	-60.9
A-02-02 14CBC2	988	945	-43.2
A-02-02 15DCA	975	941	-33.8
A-02-02 16DDD	961	928	-33.3
A-02-02 17ACB	939	910	-29.1
A-02-02 17ADA	969	916	-52.7
A-02-02 18DDD	928	907	-21.1
A-02-02 19CCB	899	899	0
A-02-02 27ACB	961	935	-25.6
A-02-02 27DCB1	958	934	-24
A-02-02 27DCB2	958	934	-24.1
A-02-02 28ABB1	948	924	-23.9
A-02-02 28ABB2	945	925	-19.8
A-02-02 28BDD	947	923	-23.8
A-02-02 29ACC	933	910	-22.6
A-02-02 29BCB	919	906	-12.8
A-02-02 30BAB	910	900	-9.9
A-02-02 30DBB	914	905	-9.5
A-02-02 31ADA	921	908	-12.8
A-02-02 32ABB	928	912	-15.7
A-02-02 32DAA	935	918	-17.1
A-02-03 07CAA	1068	1002	-66.1
A-02-03 07DAB	1034	1006	-28.3
A-02-03 07DCC2	1076	996	-79.6
A-02-03 09CDA	1051	1045	-6
A-02-03 13DAC2	1193	1115	-77.9
A-02-03 14DCA	1139	1088	-51
A-02-03 14DCD	1136	1086	-49.9
A-02-03 17ADD	1051	1018	-32.9
A-02-03 19BCD	1053	977	-76.1
A-02-03 20ADD2	1056	1006	-50.4
A-02-03 20DDA1	1044	1001	-43.2
A-02-03 25BBB2	1132	1081	-51.5
A-02-03 25CBB	1125	1074	-51.4
A-02-03 35BBC	1051	1031	-20.4
A-02-04 30ADD	1202	1135	-66.9
A-03-01 01CDC	794	868	74.3
A-03-01 02BBB	806	846	39.8
A-03-01 04BAA2	791	823	32.1
A-03-01 04DBB	796	822	26.4
A-03-01 04DDD2	793	837	44.4
A-03-01 05ABB2	776	814	37.8
A-03-01 05BBB2	772	808	36.3
A-03-01 07BAD	731	817	85.7
A-03-01 08BAA	776	818	41.9
A-03-01 09BBC	796	822	26.1
A-03-01 10BBB	787	840	53.1
A-03-01 11DDA	869	875	5.7
A-03-01 12CDB	823	874	51.2
A-03-01 16DAA	830	857	26.8
A-03-01 17ABB2	800	823	23.3
A-03-01 18CDD1	755	822	67.5
A-03-01 18DCB	784	819	35.2
A-03-01 19CCD	797	834	37.3
A-03-01 20BBB	815	825	10.4
A-03-01 21CBB	859	846	-13.2
A-03-01 23AAD	837	883	46.2
A-03-01 24CBB	872	884	12.1
A-03-01 25CDD	844	893	49.1
A-03-01 26ADD	882	891	9
A-03-01 26DDD2	879	892	12.6
A-03-01 29BBB	829	839	10.2
A-03-01 30BAA	804	835	30.5
A-03-01 31ACA	832	851	18.7
A-03-01 32DBB	866	863	-2.9
A-03-01 33DDD	915	887	-28.3
A-03-01 35ABB	902	892	-9.6
A-03-02 03AAB	895	918	23.3
A-03-02 06DAA	877	903	25.7
A-03-02 07CAD	862	882	19.9
A-03-02 08BBA2	881	901	19.9
A-03-02 09DAA	905	909	4.2
A-03-02 09DBB	911	909	-2.4
A-03-02 10BDC	906	910	3.5
A-03-02 15ACD	928	917	-11.4
A-03-02 15DDD	941	920	-21.4
A-03-02 16DAA	932	913	-18.6
A-03-02 17DCB	905	905	0.1
A-03-02 19AAD2	899	901	2.1
A-03-02 20AAA2	916	907	-8.5
A-03-02 22BAA	948	917	-30.8
A-03-02 22DBB	959	919	-40.2
A-03-02 24BAB2	947	921	-25.9
A-03-02 24CCB	965	931	-34.3
A-03-02 25BDA	992	941	-51.4
A-03-02 25DBC1	990	945	-44.5
A-03-02 26AAD	985	934	-50.8
A-03-02 26BAA2	974	929	-45.1
A-03-02 26CBC2	979	929	-50.1
A-03-02 26CCA	987	932	-55
A-03-02 26DCB	985	935	-49.7
A-03-02 29DDA2	932	906	-26.5
A-03-02 30BAA	897	899	1.8
A-03-02 30CCC2	913	896	-16.9
A-03-02 30DAD	919	900	-19.2
A-03-02 31DDA	931	900	-31.1
A-03-02 33DAA	920	918	-1.8
A-03-03 30CBC	997	936	-60.6
A-03-03 30CDA	1011	958	-52.7
A-04-01 06BBC	1048	976	-71.7
A-04-01 06CCD	1068	923	-145.2
A-04-01 08BAA	1010	933	-77.4
A-04-01 14CBB	825	870	44.8
A-04-01 18DAA	825	868	42.5
A-04-01 21CDD	778	842	64.3
A-04-01 22AAA	812	861	49.3

A-01-03 18BBC	987	964	-22.7
A-01-03 18DDD	1002	985	-16.6
A-01-03 27CAA	1030	1051	20.6
A-01-03 35ADD	1060	1091	30.7
A-01-03 35BAA	1047	1080	33.2
A-01-03 36BCC	1059	1092	33
A-01-04 19ACC	1078	1100	22.4
A-01-04 20BDC	1089	1112	22.9
A-01-04 20CAA	1079	1112	33.4
A-01-04 30BAB	1083	1100	16.9
A-01-04 30BDD	1086	1102	15.6
A-02-01 02DDD2	945	928	-17.4
A-02-01 04CBB2	931	902	-29.1
A-02-01 06ACC	882	871	-11
A-02-01 08CAA	916	893	-23.3
A-02-01 08CDD2	913	889	-24
A-02-01 08DDD	923	901	-22.5
A-02-01 09CBB2	932	900	-31.9
A-02-01 09DDD2	949	912	-36.6
A-02-01 11BAA	947	927	-20.2
A-02-01 11DDD2	950	927	-23.5
A-02-01 12DDA	961	934	-26.8
A-02-01 13CCC2	939	924	-15.2
A-02-01 14ACC	943	920	-23.5
A-02-01 14BBA	942	920	-22.2
A-02-01 14CCC	939	916	-23
A-02-01 15ABB	947	916	-30.7
A-02-01 15CBB	948	911	-36.9
A-02-01 17CAB2	913	887	-26.1
A-02-01 17DDD2	930	902	-27.8
A-02-01 18AAA1	901	881	-20
A-02-01 20BBB	911	886	-24.7
A-02-01 20BCC2	911	889	-21.6
A-02-01 20CAC	908	892	-16.1
A-02-01 20CCC2	908	891	-17.4
A-02-01 20DAA	927	902	-25.1
A-02-01 20DCC	912	895	-17.2
A-02-01 20DDD2	923	901	-21.8
A-02-01 21AAA2	928	909	-19.1
A-02-01 23CCC	932	916	-16.5
A-02-01 23DDA	939	921	-17.8
A-02-01 24DBA	945	927	-17.7
A-02-01 27ABB	931	914	-17.4
A-02-01 28AAA1	929	910	-18.9
A-02-01 29CAA2	909	896	-12.7
A-02-01 29DDD2	917	902	-14.7
A-02-01 30CAA2	900	886	-13.6
A-02-01 30CBB	895	883	-11.9
A-02-01 30DAA2	905	890	-14.9
A-02-01 30DDD2	902	893	-8.9
A-02-01 32AAC	913	901	-12
A-02-01 32DAB2	914	902	-12.4
A-02-01 32DDA	906	903	-3.4
A-02-01 33ACC	917	906	-10.6
A-02-01 33CCC	919	905	-14
A-02-01 33CDD2	919	908	-11.3
A-02-01 34BBB2	920	910	-10.3
A-02-01 35DDD	937	923	-14.3
A-02-01 36DAD	940	927	-12.7
A-02-02 01ADB1	1034	992	-41.8
A-02-02 01ADB2	1014	993	-21.4
A-02-02 02ABC	995	960	-35
A-02-02 03AAD	990	949	-40.9
A-02-02 04CAB	963	933	-29.8
A-02-02 06ACB	928	924	-3.6
A-02-02 08BBC1	946	934	-12.1
A-02-02 08BBC2	952	934	-17.9
A-02-02 09ADD2	974	947	-27.2
A-02-02 09BAD	956	941	-15
A-02-02 14CBC2	1005	961	-44.3
A-02-02 14DBB	1024	968	-56.2
A-02-02 15DCA	998	957	-40.5
A-02-02 16DDC	981	949	-31.9
A-02-02 17ACB	940	938	-2
A-02-02 17ADA	972	944	-28.3
A-02-02 18DDD	962	936	-26.4
A-02-02 19CCB	945	929	-16.1
A-02-02 20ADD	972	941	-30.6
A-02-02 22DAA	1007	958	-49.5
A-02-02 24AAA	1075	990	-85.2
A-02-02 25BCA	1005	967	-37.8
A-02-02 26BDC	991	957	-34.4
A-02-02 26CDB	1001	955	-46.1
A-02-02 27ACB	985	950	-35.2
A-02-02 27DCB1	985	950	-35.3
A-02-02 27DCB2	985	950	-35.4
A-02-02 28ABB1	979	944	-35.2
A-02-02 28ABB2	977	944	-33.4
A-02-02 28BDD	979	943	-36.5
A-02-02 29ACC	964	935	-28.7
A-02-02 29BCB	958	933	-25.1
A-02-02 30BAB	948	929	-18.8
A-02-02 30BAD1	951	930	-20.5
A-02-02 30BAD2	950	930	-19.7
A-02-02 30DBB	948	931	-17.5
A-02-02 31ADA	952	932	-19.7
A-02-02 32ABB	959	935	-23.6
A-02-02 32DAA	962	938	-23.7
A-02-03 07CAA	1067	1014	-53.2
A-02-03 07DAB	1061	1021	-39.9
A-02-03 07DCC2	1079	1011	-67.8
A-02-03 08DDD2	1056	1042	-14.3
A-02-03 09CDA	1058	1056	-2.1
A-02-03 13DAC2	1200	1121	-79.1
A-02-03 14DCA	1149	1093	-55.7
A-02-03 14DCD	1146	1092	-54.3
A-02-03 16DDA	1080	1052	-27.7
A-02-03 17ADD	1074	1034	-39.8
A-02-03 17CAA2	1066	1023	-42.6
A-02-03 18DDD2	1063	1010	-53.4
A-02-03 19BCD	1065	991	-74.1
A-02-03 20ADD2	1075	1022	-53
A-02-03 20BCC2	1068	1004	-63.5
A-02-03 20DDA1	1059	1017	-41.7
A-02-03 21DAA2	1083	1040	-43.2
A-02-03 22ABA	1104	1068	-36
A-02-03 22DDD	1106	1063	-43.2
A-02-03 24ADA	1193	1124	-69.4
A-02-03 25BBB2	1144	1090	-53.5
A-02-03 25CBB	1132	1086	-46.4

A-01-03 01DDD	1089	1088	-0.8
A-01-03 02AAB	1064	1062	-2.4
A-01-03 05ABD	1012	996	-16.2
A-01-03 05BAA	1007	992	-15.1
A-01-03 06DCD	995	981	-14.4
A-01-03 08ABB1	1012	992	-20.1
A-01-03 09ADA	1017	1017	0.2
A-01-03 13DDA	1050	1089	39.2
A-01-03 16CCB	1006	1002	-3.8
A-01-03 18BBB2	987	967	-19.7
A-01-03 18BBC	988	967	-20.5
A-01-03 20BAD2	1022	995	-26.8
A-01-03 22BBB	1025	1024	-0.7
A-01-03 23BCC	1034	1047	12.5
A-01-03 25DDC	1078	1093	15.0
A-01-03 27CAA	1030	1046	15.9
A-01-03 31DDA	1023	1025	2.3
A-01-03 33ADB	1022	1047	25.0
A-01-03 35ADD	1057	1086	28.9
A-01-03 35DDD	1073	1087	13.7
A-01-03 36ADA	1082	1095	13.1
A-01-04 19ACC	1070	1099	28.5
A-01-04 20BDC	1082	1110	27.8
A-01-04 20BDD2	1080	1112	31.8
A-01-04 20CAA	1079	1110	31.3
A-01-04 30BDD	1079	1098	18.9
A-01-04 32ACB	1096	1104	8.0
A-02-01 01DDA	943	928	-14.8
A-02-01 03BBA	947	911	-35.9
A-02-01 04CBB2	941	905	-35.5
A-02-01 06ACC	887	866	-20.7
A-02-01 08CAA	919	902	-16.8
A-02-01 08CDD2	916	900	-15.7
A-02-01 08DDD	926	911	-14.7
A-02-01 09CBB2	933	909	-23.9
A-02-01 09DDD2	946	922	-24.1
A-02-01 11BAA	924	926	2.1
A-02-01 12DDA	948	932	-16.0
A-02-01 13CCC2	914	930	15.7
A-02-01 14ACC	933	927	-6.1
A-02-01 14BBA	938	927	-10.6
A-02-01 14CCC	935	926	-9.0
A-02-01 15ABB	943	925	-17.8
A-02-01 15CBB	943	922	-21.0
A-02-01 17BAA1	918	901	-17.1
A-02-01 17CAB2	913	899	-14.0
A-02-01 17DDD2	924	912	-11.7
A-02-01 18AAA1	909	892	-17.0
A-02-01 20BBB	909	896	-13.4
A-02-01 20BCC2	908	898	-9.9
A-02-01 20CAC	910	901	-9.0
A-02-01 20CCC2	905	900	-5.4
A-02-01 20DAA	922	911	-10.7
A-02-01 20DCC	910	905	-5.5
A-02-01 20DDD2	920	911	-8.5
A-02-01 21AAA2	927	920	-7.3
A-02-01 23CCC	930	926	-4.2
A-02-01 23DDA	935	930	-4.9
A-02-01 24DBA	938	934	-4.4
A-02-01 25BCA1	934	932	-2.0
A-02-01 25BCA2	935	932	-2.9
A-02-01 26DAA	938	931	-7.3
A-02-01 27ABB	929	923	-6.0
A-02-01 28AAA1	915	920	4.9
A-02-01 29CAA2	907	907	-0.1
A-02-01 29DDD2	915	914	-1.1
A-02-01 30CAA2	895	895	0.2
A-02-01 30CBB	888	891	2.7
A-02-01 30DDD2	904	904	-0.1
A-02-01 31DAA	916	910	-6.3
A-02-01 32AAC	914	912	-1.7
A-02-01 32ACA	914	914	-0.5
A-02-01 32DAB2	914	913	-0.9
A-02-01 32DDA	909	915	5.9
A-02-01 33ACC	918	917	-0.5
A-02-01 33CDD2	918	919	1.2
A-02-01 34BBB2	920	920	-0.1
A-02-01 34BCC2	919	920	1.3
A-02-01 35DDD	938	934	-4.1
A-02-01 36DAD	944	937	-6.9
A-02-02 01ADB1	984	970	-14.0
A-02-02 01ADB2	979	971	-8.1
A-02-02 02ABC	962	928	-34.5
A-02-02 03AAD	975	919	-56.3
A-02-02 04CAB	933	921	-11.8
A-02-02 05DBC	952	927	-24.9
A-02-02 06ACB	932	922	-9.9
A-02-02 06DBA	926	927	0.6
A-02-02 08BBC2	945	931	-14.2
A-02-02 09ADD2	976	937	-39.3
A-02-02 09BAD	951	931	-19.9
A-02-02 14CBC2	984	958	-26.5
A-02-02 14DBB	1007	964	-43.4
A-02-02 16DDC	969	949	-20.2
A-02-02 17ACB	941	939	-2.4
A-02-02 17ADA	960	943	-17.3
A-02-02 18DDD	951	939	-12.4
A-02-02 19CCB	939	935	-3.8
A-02-02 20ADD	963	945	-17.7
A-02-02 22DAA	995	960	-35.4
A-02-02 25BCA	1004	970	-33.8
A-02-02 27ACB	988	956	-32.0
A-02-02 27DCB1	985	956	-29.1
A-02-02 27DCB2	987	956	-31.2
A-02-02 28ABB1	978	950	-28.4
A-02-02 28ABB2	976	949	-26.6
A-02-02 29ACC	963	943	-20.1
A-02-02 30BAB	942	936	-5.8
A-02-02 30BAD1	948	938	-10.5
A-02-02 30BAD2	947	937	-9.7
A-02-02 30DBB	947	938	-8.9
A-02-02 31ADA	954	941	-13.0
A-02-02 32ABB	960	943	-16.6
A-02-02 32DAA	964	946	-17.8
A-02-03 07CAA	1047	1005	-41.9
A-02-03 07DAB	1004	1013	9.1
A-02-03 07DCC2	1061	1004	-56.9
A-02-03 08DDD2	1030	1037	6.7
A-02-03 09CDA	1027	1049	22.3
A-02-03 13DAC2	1198	1127	-70.6

APPENDIX TABLE C-1

ADWR MODEL UNWEIGHTED CALIBRATION RESIDUALS - WSRV SUBBASIN

A-04-01 22ADA	812	860	48.2
A-04-01 22DBB	791	850	58.9
A-04-01 23BAD	819	859	39.7
A-04-01 26BDC	829	864	34.8
A-04-01 26BDD	831	865	34
A-04-01 27BAB2	772	847	75
A-04-01 28AAB	782	842	60.3
A-04-01 29BBA	795	844	48.8
A-04-01 30AAA1	805	843	37.7
A-04-01 30AAB2	800	844	43.7
A-04-01 30BAD	859	846	-12.9
A-04-01 30BCD	846	831	-15.4
A-04-01 30BDD	846	845	-0.9
A-04-01 30CCB	829	842	12.8
A-04-01 31ABB	796	825	29.5
A-04-01 31BBA2	797	833	36
A-04-01 32ABA	784	820	35.7
A-04-01 32ABB	776	818	41.7
A-04-01 32BAB	776	821	44.7
A-04-01 32CCB	778	813	34.9
A-04-01 34BDD2	788	837	48.8
A-04-01 35BAA	807	860	52.6
A-04-02 11ADB	1065	1015	-49.8
A-04-02 22AAB	901	913	12.3
A-04-02 26CBA	896	910	14.4
A-04-02 29BCD	869	912	43.1
A-04-02 32BAA2	871	913	41.9
A-04-02 35AAB	904	920	16.4
A-04-03 06BCD	1166	1179	12.7
A-05-01 33BCC	1174	1112	-62.2
B-01-01 01CAA	913	883	-29.7
B-01-01 02AAD2	921	883	-37.9
B-01-01 02BBB	894	876	-17.6
B-01-01 03DAB	872	875	3.3
B-01-01 03DBA	900	875	-24.8
B-01-01 04ABA2	838	875	36.7
B-01-01 05ABA	889	874	-14.5
B-01-01 06BBA2	874	869	-4.9
B-01-01 07ABA2	886	872	-14
B-01-01 07CAA2	880	870	-10.1
B-01-01 07DDA	914	875	-39.2
B-01-01 07DDC1	914	872	-42.1
B-01-01 07DDC2	912	872	-39.7
B-01-01 07DDD	915	872	-42.7
B-01-01 08BBA	886	873	-12.5
B-01-01 10AAA2	897	879	-17.5
B-01-01 10BCC	897	878	-19.4
B-01-01 10BDA	893	878	-14.6
B-01-01 10BDB	894	878	-16.4
B-01-01 10CBD	897	878	-18.6
B-01-01 10DDB	883	882	-0.6
B-01-01 11AAA	912	884	-28
B-01-01 11BAB	912	881	-30.6
B-01-01 11CCB1	909	883	-25.5
B-01-01 12AAA1	906	887	-19.2
B-01-01 12BAA2	913	885	-27.6
B-01-01 13DBC	920	896	-24.1
B-01-01 15BAD	895	882	-13.1
B-01-01 15CCB	899	881	-18.1
B-01-01 17AAD2	898	875	-22.7
B-01-01 18BAA	878	868	-9.6
B-01-01 18BDC2	870	866	-3.8
B-01-01 19BBA	877	862	-15.2
B-01-01 19CBA	875	860	-14.5
B-01-01 19CCC	881	860	-21.4
B-01-01 20DAA	889	872	-17
B-01-01 20DAC	890	870	-20.4
B-01-01 21CBA	891	875	-16.3
B-01-01 22ACD	906	887	-18.8
B-01-01 24ABB	911	897	-14.1
B-01-01 25BAA	915	905	-10
B-01-01 27DAB2	897	897	0.5
B-01-01 28AAB	897	881	-16.2
B-01-01 28BAA	871	873	2.2
B-01-01 28BCA2	893	874	-19.3
B-01-01 28CDC	895	876	-19
B-01-01 29ADD	895	869	-25.8
B-01-01 29CAD	888	866	-21.6
B-01-01 29CBB	887	864	-23.3
B-01-01 29DDA2	891	869	-22.5
B-01-01 30ABA	880	861	-19.4
B-01-01 30CBA	870	856	-13.8
B-01-01 30DBB	879	859	-20.4
B-01-01 32BCA	878	865	-13.3
B-01-02 01BAA	875	867	-7.8
B-01-02 01BBB2	868	866	-2.4
B-01-02 01CCC	860	865	5.3
B-01-02 02BAA	857	867	9.8
B-01-02 02BBB2	840	866	26.2
B-01-02 02CCC4	865	862	-2.7
B-01-02 02CCD	872	864	-8.2
B-01-02 02DBA	848	865	17
B-01-02 03CBB3	846	861	14.9
B-01-02 03DBB	847	862	14.9
B-01-02 03DCC	861	861	-0.5
B-01-02 03DCD	859	861	2.3
B-01-02 04DBB2	846	860	14.4
B-01-02 05AAA	849	859	10.1
B-01-02 05CBB	850	858	7.9
B-01-02 08ABB2	854	858	3.7
B-01-02 08BCC	850	856	5.8
B-01-02 09ABB	884	858	-25.5
B-01-02 09ACC	857	857	0.1
B-01-02 09ADA2	849	858	8.9
B-01-02 09BAA	840	858	18.5
B-01-02 09BBB2	848	858	9.9
B-01-02 09CBC	869	856	-13.1
B-01-02 11ABB	877	864	-13.1
B-01-02 11BCC	843	861	17.8
B-01-02 12DAA2	885	869	-16
B-01-02 12DAD	880	869	-11.3
B-01-02 13ABA	908	865	-43.4
B-01-02 13BCA	882	862	-20.2
B-01-02 13DCA2	882	861	-21.2
B-01-02 13DCD	873	861	-12.3
B-01-02 14BAA1	878	862	-16
B-01-02 14CAA	869	860	-8.8
B-01-02 14CDA	871	859	-12.2
B-01-02 14DDB	874	860	-14.2
B-01-02 15CCC	865	854	-11.4

A-02-03 33DCC	1025	1011	-14.4
A-02-03 35AAD	1109	1075	-33.6
A-02-03 35BBC	1065	1048	-16.7
A-02-03 36AAA2	1156	1105	-50.7
A-02-04 20CCC	1226	1147	-78.9
A-02-04 30ACC1	1194	1131	-63.2
A-02-04 30ADD	1209	1146	-63
A-02-04 30CDD	1175	1120	-55.4
A-03-01 02BBB	792	839	47
A-03-01 04BAA2	790	822	31.9
A-03-01 04BAA3	788	824	35.8
A-03-01 04DBB	798	825	26.9
A-03-01 04DDD1	784	840	55.6
A-03-01 05ABB2	781	816	35
A-03-01 05BBB2	782	813	30.9
A-03-01 07BAD	786	824	38.1
A-03-01 07DBA	793	823	30.5
A-03-01 08BAA	791	823	32.4
A-03-01 09BBC	760	825	64.8
A-03-01 11DDA	881	886	5.4
A-03-01 12AAD	826	881	54.8
A-03-01 12CDB	815	885	69.8
A-03-01 16DAA	793	862	69.1
A-03-01 17ABB2	815	831	15.6
A-03-01 17ACC	860	825	-35.3
A-03-01 17DBC	830	818	-12.3
A-03-01 18DCB	805	833	28.1
A-03-01 19CCD	811	845	34.2
A-03-01 19DBA	818	841	23.4
A-03-01 20BBB	875	837	-38.4
A-03-01 21ADA	877	876	-0.8
A-03-01 21BDD	866	868	2.1
A-03-01 22DDA3	911	897	-13.6
A-03-01 24CBB	892	898	5.8
A-03-01 25ABB	834	903	69.2
A-03-01 25CDD	775	908	133.4
A-03-01 26ADD	911	906	-4.5
A-03-01 26DDD2	907	908	1.1
A-03-01 27CCC	937	912	-25.2
A-03-01 30BAA	831	846	15.2
A-03-01 32DBB	857	882	24.9
A-03-01 33DDD	942	919	-22.8
A-03-01 34DDD2	923	919	-3.6
A-03-01 35ABB	925	912	-13.1
A-03-01 35DDD	937	917	-19.8
A-03-01 36CCA	944	913	-30.8
A-03-02 01ABB	903	923	20.1
A-03-02 03AAB	869	903	34.1
A-03-02 03DDD	892	900	8.3
A-03-02 06DAA	863	894	30.6
A-03-02 07CAD	864	886	22.2
A-03-02 08BBA2	864	894	29.7
A-03-02 08DAB	886	897	10.8
A-03-02 09CAA	910	898	-11.5
A-03-02 09DAA	878	898	20.2
A-03-02 09DBB	874	898	24.1
A-03-02 10BDC	882	898	15.5
A-03-02 11BDC	909	906	-2.7
A-03-02 11CAA	912	909	-3.2
A-03-02 14CAB	932	909	-22.8
A-03-02 15ACD	904	907	3.4
A-03-02 15DDD	929	910	-19.3
A-03-02 16DAA	928	907	-21.4
A-03-02 17DCB	916	904	-12.2
A-03-02 19AAD2	921	905	-16.1
A-03-02 20AAA2	896	907	10.8
A-03-02 22BAA	940	910	-30.2
A-03-02 22DBB	1028	911	-116.5
A-03-02 23BCC	950	913	-36.9
A-03-02 24BAB2	930	910	-20.1
A-03-02 24CCB	968	921	-47
A-03-02 25BAB	983	926	-56.9
A-03-02 25BDA	991	935	-56.4
A-03-02 25CAC	995	941	-54.1
A-03-02 25DBC1	989	944	-45.5
A-03-02 26AAD	983	926	-56.8
A-03-02 26BAA2	1007	920	-86.8
A-03-02 26CBC2	977	924	-52.9
A-03-02 26CCA	987	927	-60.2
A-03-02 26DDB	986	934	-51.8
A-03-02 27BAD	972	915	-56.6
A-03-02 27BBB	955	912	-42.9
A-03-02 29DDA2	943	915	-28.3
A-03-02 30ADA	931	911	-19.6
A-03-02 30BAA	921	909	-11.5
A-03-02 30CCC2	934	913	-20.5
A-03-02 30DAD	938	913	-24.8
A-03-02 31DDA	954	923	-30.6
A-03-02 34ADA	986	931	-54.9
A-03-02 36BDA	1002	961	-40.6
A-03-03 30CAC2	1003	957	-46.2
A-03-03 30CBC	997	950	-46.8
A-03-03 30CDA	1013	971	-41.8
A-04-01 06CCD	986	939	-47
A-04-01 06DCD1	1013	961	-52
A-04-01 08DBD	945	910	-34.9
A-04-01 10ACA	955	887	-67.8
A-04-01 18DAA	889	884	-5.3
A-04-01 21CDD	791	845	54.5
A-04-01 22AAA	817	853	35.9
A-04-01 22ADB	795	844	48.8
A-04-01 29BBA	804	850	45.8
A-04-01 30AAA1	792	849	57
A-04-01 30AAB2	797	851	53.6
A-04-01 30BCC	844	856	11.6
A-04-01 30BCD	836	829	-6.9
A-04-01 30CCB	835	853	18.2
A-04-01 32ABB	833	808	-24.9
A-04-01 32BAB	787	820	32.7
A-04-02 11ADB	1067	1011	-56.1
A-04-02 12ACB	1091	1067	-23.7
A-04-02 14BBB	906	939	33.4
A-04-02 22AAB	879	901	22
A-04-02 26CBA	874	893	18.7
A-04-02 33DBB2	849	895	45.9
A-04-02 34BDD	868	901	32.9
A-04-02 35AAB	883	904	21.4
A-05-01 31DAD	1077	1050	-26.6
B-01-01 01BAC	909	892	-17.5
B-01-01 01CAA	917	893	-24

A-02-03 14DCA	1143	1100	-43.5
A-02-03 14DCD	1139	1098	-41.4
A-02-03 16DDA	1062	1052	-9.9
A-02-03 17ADD	1037	1030	-6.7
A-02-03 17CAA2	1045	1019	-25.7
A-02-03 18DDD2	1045	1006	-38.9
A-02-03 20BCC2	1059	1002	-56.8
A-02-03 21DAA2	1072	1039	-32.6
A-02-03 22ABA	1090	1070	-19.6
A-02-03 22DDD	1097	1064	-33.2
A-02-03 24ADA	1191	1126	-65.2
A-02-03 25BBB2	1135	1091	-43.5
A-02-03 25CBB	1132	1085	-47.4
A-02-03 28CAA	1040	1018	-21.7
A-02-03 35BBC	1062	1050	-12.4
A-02-03 36AAA2	1157	1100	-56.8
A-02-04 20CCC	1224	1144	-79.6
A-02-04 30ACC1	1192	1126	-65.6
A-02-04 30ADD	1194	1142	-51.7
A-02-04 30CCA	1170	1108	-61.5
A-03-01 01BBA	828	849	20.8
A-03-01 03ABA2	816	841	24.7
A-03-01 04DBB	803	828	25.0
A-03-01 04DDD1	794	842	47.7
A-03-01 05ABB2	788	822	33.5
A-03-01 06DAD	787	826	39.3
A-03-01 11DDA	892	878	-13.8
A-03-01 12CDB	832	876	43.6
A-03-01 14DDD	911	898	-13.0
A-03-01 16DAA	813	869	56.1
A-03-01 17ABB2	835	834	-1.3
A-03-01 21ADA	885	881	-4.0
A-03-01 22DDA3	913	901	-12.1
A-03-01 24CBB	891	898	7.2
A-03-01 25ABB	856	904	47.6
A-03-01 26ADD	906	910	3.8
A-03-01 27CCC	938	915	-23.0
A-03-01 30BAA	826	838	11.7
A-03-01 32ABA2	897	878	-18.9
A-03-01 32DBB	883	880	-2.8
A-03-01 33DDD	945	924	-21.0
A-03-01 34DDD2	916	924	8.1
A-03-01 35ABB	920	917	-3.2
A-03-01 35DDD	934	919	-14.7
A-03-02 01ABB	857	878	20.9
A-03-02 03AAB	840	861	20.9
A-03-02 03DDD	850	857	6.9
A-03-02 04BAA	847	862	15.0
A-03-02 04CCD	866	861	-4.9
A-03-02 06DAA	851	868	16.9
A-03-02 09DAA	853	861	7.7
A-03-02 09DBB	854	866	11.8
A-03-02 10DBA	858	858	0.0
A-03-02 11BDC	860	860	0.5
A-03-02 11CAA	863	862	-1.2
A-03-02 15ACD	885	866	-18.6
A-03-02 15DDD	902	866	-36.0
A-03-02 16DAA	913	872	-40.9
A-03-02 17BCC	856	884	28.3
A-03-02 17DCB	912	887	-25.4
A-03-02 19AAD2	916	892	-24.5
A-03-02 20AAA2	922	884	-38.0
A-03-02 22BAA	920	871	-49.3
A-03-02 22DBB	917	871	-46.4
A-03-02 23BCC	924	866	-57.5
A-03-02 24BAB2	885	857	-27.7
A-03-02 25BAB	946	870	-75.9
A-03-02 25BDA	952	877	-75.0
A-03-02 25CAC	955	881	-73.9
A-03-02 25DBC1	956	884	-72.5
A-03-02 26AAD	950	869	-80.5
A-03-02 26BAA2	938	867	-71.3
A-03-02 26CCA	945	868	-76.9
A-03-02 26DDB	949	875	-73.6
A-03-02 27BAD	931	875	-56.4
A-03-02 27BBB	935	877	-57.5
A-03-02 29BBA	919	895	-24.1
A-03-02 30BAA	924	902	-21.9
A-03-02 30CCC2	932	914	-18.1
A-03-02 30DAD	937	903	-33.8
A-03-02 31DDA	947	919	-27.9
A-03-02 33DAA	942	896	-45.8
A-03-02 34ADA	953	887	-65.5
A-03-02 36BDA	965	916	-48.8
A-03-03 30CAC1	962	903	-58.7
A-03-03 30CBC	958	890	-67.8
A-03-03 30CDA	976	928	-47.9
A-04-01 04BBB1	1130	1055	-74.9
A-04-01 05ACD	1059	1027	-31.6
A-04-01 08DBD	960	922	-37.9
A-04-01 13CBB	849	838	-11.4
A-04-01 14DAD	764	832	68.1
A-04-01 15BDD	810	864	54.1
A-04-01 18DAA	900	895	-5.3
A-04-01 22AAA	804	842	37.7
A-04-01 23ADB	754	801	46.8
A-04-01 27AAA	804	833	29.0
A-04-01 27BAB1	791	838	47.0
A-04-01 28AAB	794	848	53.5
A-04-01 34ABA1	798	833	35.1
A-04-01 34BBA	785	830	45.2
A-04-01 35BBC	811	835	24.0
A-04-02 11ADB	1068	1010	-58.4
A-04-02 12ACB	1093	1069	-23.8
A-04-02 14BBB	920	932	11.7
A-04-02 16ABB	868	903	34.5
A-04-02 19BCC	826	821	-5.1
A-04-02 27DDD	837	853	15.7
A-04-02 29BCD	840	843	3.3
A-04-02 32BAA2	825	847	22.4
A-04-02 32CAA	831	855	23.9
A-04-02 32DDA	840	859	19.3
A-04-02 33DBB2	824	855	31.0
A-04-02 34BDD	839	860	20.7
A-04-03 06BCD	1214	1180	-34.1
A-04-03 07BCD1	1088	1085	-3.0
A-05-01 33BCC	1177	1107	-70.0
B-01-01 01BAC	913	898	-14.8
B-01-01 01BAD	914	897	-16.6
B-01-01 01BDA	913	898	-15.0

APPENDIX TABLE C-1

ADWR MODEL UNWEIGHTED CALIBRATION RESIDUALS - WSRV SUBBASIN

B-01-02 16BBB	850	855	4.8
B-01-02 17BBC	859	853	-6.2
B-01-02 17CAA	852	853	0.5
B-01-02 17CBB	853	852	-1.1
B-01-02 17CCC	853	851	-2.2
B-01-02 18ACC	850	851	1.5
B-01-02 18ACD	819	851	32.3
B-01-02 20BBB	859	851	-8.2
B-01-02 21CBA	862	851	-11.4
B-01-02 21DCA4	860	850	-10.3
B-01-02 22DBA1	865	852	-12.7
B-01-02 22DBC	866	851	-15
B-01-02 22DDC	864	848	-15.6
B-01-02 23AAB1	875	859	-16.2
B-01-02 23CAD1	869	854	-15.5
B-01-02 23CAD2	867	853	-14.1
B-01-02 25BBC1	866	864	-1.8
B-01-02 25DBA2	873	853	-20.1
B-01-02 26BDC	863	839	-24
B-01-02 26CCC	858	837	-20.8
B-01-02 27CAA	861	845	-16.1
B-01-02 27CBB1	862	845	-16.7
B-01-02 27DAD	861	838	-23.3
B-01-02 28CBD	857	844	-13.5
B-01-02 28DBB	860	844	-16.2
B-01-02 29CBA	831	843	11.5
B-01-02 29CCC	851	840	-11.2
B-01-02 29DCA	858	841	-17.5
B-01-02 30ABB	854	845	-8.5
B-01-02 31DCC1	847	835	-11.6
B-01-02 32DCB	850	838	-11.8
B-01-02 34ABB	857	841	-16.4
B-01-02 36BBC	867	849	-18.2
B-01-03 13CBC	845	849	3.9
B-01-03 14AAB	838	850	11.6
B-01-03 14DBB	839	849	10.5
B-01-03 17ADA	845	862	17.1
B-01-03 19CBB	868	859	-9.4
B-01-03 20CAA	855	859	3.6
B-01-03 21DBB	849	855	6.2
B-01-03 22AAD	858	849	-9
B-01-03 23ACB	827	848	21.2
B-01-03 23CBB	844	848	4
B-01-03 25BBB	851	845	-5.9
B-01-03 25BBC1	852	844	-8.3
B-01-03 27CBB	852	846	-6.3
B-01-03 28CBB	853	850	-3.5
B-01-03 29BAA	857	855	-1.8
B-01-03 30BAA	852	856	4.4
B-01-03 31BCB	852	846	-6.4
B-01-03 31DDA	821	842	20.8
B-01-03 32BAA	850	846	-3.5
B-01-03 34ADD2	846	833	-13.4
B-01-03 34BBB1	850	842	-7.8
B-01-03 34CAD	845	832	-12.7
B-01-03 34CCB	845	835	-10.1
B-01-03 35BDD2	850	833	-17
B-01-03 36AAB	852	840	-12.1
B-01-03 36BBD	849	835	-14
B-01-04 16DBA	876	908	32.1
B-01-04 16DCD	877	898	21.3
B-01-04 19AAA	934	913	-21.2
B-01-04 19BAA	928	917	-11
B-01-04 19BBB2	930	920	-10.1
B-01-04 19DAD2	956	896	-59.9
B-01-04 20DDA2	929	888	-40.8
B-01-04 25AAC	849	856	7.5
B-01-04 25DBC	852	851	-1.1
B-01-04 27AAD	856	866	9.8
B-01-04 27ABB	869	872	2.6
B-01-04 27DBC	858	861	3.4
B-01-04 28DAA	864	869	4.7
B-01-04 29AAD	864	879	14.5
B-01-04 29ACC	888	878	-9.7
B-01-04 31BCD	850	869	19
B-01-04 32ABA	858	868	9.7
B-01-04 32BBB2	844	869	25
B-01-04 32DAA	852	859	6.5
B-01-04 33BDA	853	860	7.3
B-01-04 34BBA	854	856	2.2
B-01-04 34BCD	848	852	3.9
B-01-04 35AAD	847	846	-0.7
B-01-04 35BBC	852	851	-1
B-01-04 36BBB	854	849	-5.2
B-01-05 24ABA	927	925	-1.8
B-01-05 35ABA	858	892	33.8
B-01-05 36AAA	854	881	26.5
B-01-05 36CCB	827	871	43.9
B-02-01 01CCC2	816	844	28.4
B-02-01 04DAA	811	817	6
B-02-01 04DCB	720	813	92.9
B-02-01 05AAB	733	803	70.1
B-02-01 05ABC2	728	802	73.9
B-02-01 06ABB2	794	792	-2
B-02-01 06ABB3	787	789	2.3
B-02-01 06CBB	774	790	15.7
B-02-01 06DBB1	778	791	12.7
B-02-01 07ABB	785	795	9.7
B-02-01 07CAD	787	800	12.5
B-02-01 07CBB1	789	794	5.5
B-02-01 08ADA	744	812	68.4
B-02-01 09BCB1	730	814	83.8
B-02-01 12ABC2	967	857	-109.6
B-02-01 12BAC	788	853	64.9
B-02-01 12BDD3	844	851	7.2
B-02-01 13BAD	845	852	7.2
B-02-01 14ABD2	815	850	34.7
B-02-01 18BBB2	789	795	6.3
B-02-01 18CBB2	796	803	6.7
B-02-01 19AAB2	818	824	5.7
B-02-01 19BAA	819	819	-0.4
B-02-01 19BBB2	802	812	10.3
B-02-01 19DBB2	823	830	6.8
B-02-01 23DDD	841	858	16.9
B-02-01 24BBD	847	854	7.4
B-02-01 25ADC	862	870	7.6
B-02-01 25BBB	838	858	19.8
B-02-01 26ACA	857	863	5.8
B-02-01 26CBC2	874	867	-7.4
B-02-01 27CBC	887	868	-19.3

B-01-01 02BBB	902	883	-18.8
B-01-01 03BAA	897	882	-15
B-01-01 03DAC	904	886	-17.8
B-01-01 04ABA2	893	880	-12.7
B-01-01 04BCC	896	881	-15.3
B-01-01 05ABA	888	875	-12.9
B-01-01 05CDC1	893	878	-15.2
B-01-01 06BBA2	869	870	0.6
B-01-01 07ABA2	894	876	-17.9
B-01-01 07CAA2	889	876	-12.8
B-01-01 07DDA	916	882	-34.3
B-01-01 07DDC1	919	879	-40.4
B-01-01 07DDC2	924	877	-46.8
B-01-01 07DDD	921	879	-41.7
B-01-01 08BBA	895	879	-16.3
B-01-01 09DDB	900	885	-14.6
B-01-01 10AAA2	906	888	-18.5
B-01-01 10BDA	900	886	-13.9
B-01-01 10CBB	903	886	-17.3
B-01-01 10CCD	896	887	-8.5
B-01-01 10DCC	863	889	26.1
B-01-01 10DDB	908	890	-18.5
B-01-01 11AAA	921	892	-28.7
B-01-01 11AAB	920	892	-28
B-01-01 11BAB	919	890	-29.4
B-01-01 11CCB1	920	891	-29
B-01-01 12AAA1	918	897	-20.8
B-01-01 12BAA2	911	895	-15.8
B-01-01 13DBC	926	904	-22.1
B-01-01 15BAD	900	890	-10.5
B-01-01 15CCB	904	888	-16
B-01-01 15DCA	908	892	-16
B-01-01 18AAB	898	878	-20.2
B-01-01 18BAA	887	876	-10.8
B-01-01 18BDC2	886	876	-10.3
B-01-01 19BBA	886	873	-12.9
B-01-01 19CBA	883	873	-9.7
B-01-01 19CCC	880	874	-6.3
B-01-01 20DAA	893	881	-12.1
B-01-01 20DAC	894	879	-14.7
B-01-01 21CBA	895	883	-11.7
B-01-01 22ACD	910	895	-14.8
B-01-01 24ABB	922	906	-16.4
B-01-01 25ADA	926	914	-11.6
B-01-01 25BAA	923	910	-12.6
B-01-01 27DAB2	910	904	-6.1
B-01-01 28AAB	902	889	-12.7
B-01-01 28ABA	900	889	-11.5
B-01-01 28BCA2	897	881	-16.3
B-01-01 28CDC	895	882	-13
B-01-01 29ADD	899	877	-21.8
B-01-01 29CAD	891	874	-16.9
B-01-01 29CBB	891	872	-18.8
B-01-01 29DDA2	892	876	-16.4
B-01-01 30CBA	880	870	-10.1
B-01-01 30DBB	885	871	-13.8
B-01-01 32BCA	880	872	-7.8
B-01-02 01BAA	859	866	6.8
B-01-02 01CCC	853	871	18.4
B-01-02 02BBB1	845	869	23.9
B-01-02 02BBB2	841	866	24.9
B-01-02 02CCC4	863	870	7.3
B-01-02 02CCD	867	870	3.2
B-01-02 02DBA	861	870	9.4
B-01-02 03DCC	859	870	11
B-01-02 04DBB2	847	868	21.1
B-01-02 05AAA	847	864	17.2
B-01-02 05CBB	848	864	16.1
B-01-02 08ABB2	856	867	10.8
B-01-02 08BBB2	854	865	11.4
B-01-02 08BCC	855	866	10.8
B-01-02 08DDA2	867	868	1.1
B-01-02 09ABB	866	869	2.7
B-01-02 09ACC	866	869	3.4
B-01-02 09ADA2	856	869	13.5
B-01-02 09BAA	854	869	14.5
B-01-02 09BBB2	858	868	9.9
B-01-02 09CBC	866	868	2.4
B-01-02 11ABB	877	871	-5.6
B-01-02 11BCC	857	871	14.4
B-01-02 12DAD	888	876	-12.3
B-01-02 13AAA	890	875	-15.3
B-01-02 13ABA	870	875	5
B-01-02 13DCA2	882	874	-8.2
B-01-02 13DCD	883	873	-9.6
B-01-02 14BAA1	885	874	-11.1
B-01-02 14BAD	877	874	-3.2
B-01-02 14CAA	877	873	-3.5
B-01-02 14CDA	877	873	-4
B-01-02 14DDB	883	873	-9.6
B-01-02 15CCC	873	869	-3.8
B-01-02 16ABB	872	870	-2.4
B-01-02 16BBB	856	868	12.1
B-01-02 17BBC	865	865	0.2
B-01-02 17CAA	863	866	3.1
B-01-02 17CBB	866	865	-1
B-01-02 17DBD	865	867	1.8
B-01-02 18AAB	884	865	-19.2
B-01-02 18ACC	857	864	7.1
B-01-02 20BBB	864	864	0.5
B-01-02 20CBA	867	864	-3
B-01-02 21ABB	859	868	8.8
B-01-02 21BCC	866	866	0.4
B-01-02 21CBA	868	866	-1.5
B-01-02 21DCA3	869	867	-2.1
B-01-02 22DBA1	867	871	3.7
B-01-02 22DCC	872	869	-3.3
B-01-02 23AAB1	876	874	-2.3
B-01-02 23AAB2	870	873	3.2
B-01-02 23CAD2	875	871	-3.5
B-01-02 24DAA	882	873	-8.8
B-01-02 25BBC1	875	874	-1.1
B-01-02 25DBA2	882	871	-11.1
B-01-02 26BCB	871	867	-4
B-01-02 26BDC	871	866	-5.1
B-01-02 26CCC	867	863	-4.1
B-01-02 27CAA	869	866	-3.5
B-01-02 27DAD	870	863	-7
B-01-02 28CBD	865	863	-2
B-01-02 29CBA	847	861	14.1

B-01-01 01CAA	919	901	-18.0
B-01-01 01CAB	918	899	-18.7
B-01-01 02BBB	901	886	-15.2
B-01-01 02BCB	902	888	-14.2
B-01-01 02DAA	915	896	-19.2
B-01-01 03BAA	897	884	-13.4
B-01-01 03DAC	901	890	-11.4
B-01-01 04AAB	891	881	-9.8
B-01-01 04ABA2	892	881	-11.5
B-01-01 04BCC	893	879	-13.7
B-01-01 04CAA	894	882	-11.8
B-01-01 05ABA	881	871	-9.6
B-01-01 05BBB2	878	868	-10.3
B-01-01 05CDC1	888	875	-13.2
B-01-01 06BBA2	858	861	3.5
B-01-01 07ABA2	886	872	-14.3
B-01-01 07BBB	898	869	-29.1
B-01-01 07CAA2	884	873	-11.4
B-01-01 09AAB	904	885	-18.8
B-01-01 09DDB	906	887	-19.1
B-01-01 10AAA2	908	891	-16.8
B-01-01 10ACD	908	891	-16.6
B-01-01 10BDA	902	889	-13.1
B-01-01 10CBB	904	888	-16.4
B-01-01 10CBD	893	888	-4.6
B-01-01 10CCD	900	889	-10.6
B-01-01 11AAA	922	899	-23.2
B-01-01 11AAB	921	898	-23.1
B-01-01 11BAB	923	895	-28.1
B-01-01 11CCB1	923	895	-28.2
B-01-01 11CCB2	922	895	-26.9
B-01-01 12BAA2	918	904	-14.1
B-01-01 13DBC	929	911	-18.3
B-01-01 15BAD	904	892	-11.9
B-01-01 15CCB	906	890	-15.6
B-01-01 16AAB	907	888	-19.2
B-01-01 16AAC	902	888	-14.2
B-01-01 16ADB	904	888	-16.0
B-01-01 16DBD	901	888	-12.9
B-01-01 17AAD2	897	883	-13.5
B-01-01 18AAB	892	876	-16.3
B-01-01 18BAA	885	873	-11.7
B-01-01 18BDC2	882	874	-8.1
B-01-01 19CBA	886	874	-12.1
B-01-01 19CCC	877	874	-3.1
B-01-01 20BBB1	889	878	-11.2
B-01-01 20DAA	893	883	-10.0
B-01-01 21CBA	895	886	-9.5
B-01-01 22ACD	913	897	-16.1
B-01-01 25ADA	928	917	-11.1
B-01-01 25BAA	925	913	-11.6
B-01-01 27DAB1	910	902	-7.6
B-01-01 27DAB2	906	903	-3.5
B-01-01 28AAB	902	890	-11.5
B-01-01 28ABA	902	890	-12.1
B-01-01 28BCA2	897	884	-13.2
B-01-01 30ACC	858	875	16.5
B-01-01 34AAA	914	908	-5.7
B-01-02 01BBB2	826	854	28.1
B-01-02 01CCC	847	865	17.6
B-01-02 02CCC4	855	862	7.1
B-01-02 02CCD	859	862	3.3
B-01-02 03ABB2	816	854	38.5
B-01-02 03BBB	819	853	34.2
B-01-02 03DBB	848	860	11.8
B-01-02 03DCC	851	861	10.4
B-01-02 04ACA1	833	855	22.4
B-01-02 05AAA	842	849	6.9
B-01-02 05CBB	839	850	11.0
B-01-02 08ABB2	851	853	2.5
B-01-02 08BBB1	856	852	-4.3
B-01-02 08BBB2	847	852	4.8
B-01-02 08BCC	852	854	2.3
B-01-02 08DDA2	858	860	1.7
B-01-02 09ABB	856	858	2.5
B-01-02 09ACC	856	861	4.5
B-01-02 09ADA2	847	861	13.5
B-01-02 09BBB2	850	857	6.8
B-01-02 10BBB3	860	860	0.4
B-01-02 11ABB	870	864	-5.8
B-01-02 12DAD	876	872	-4.0
B-01-02 13AAA	878	871	-6.5
B-01-02 13BCA	884	870	-13.6
B-01-02 13DCD	877	872	-4.9
B-01-02 14BAA1	869	868	-0.7
B-01-02 14CAA	869	870	0.6
B-01-02 14CDA	876	870	-6.1
B-01-02 14DDB	879	871	-8.2
B-01-02 15CCC	865	865	0.0
B-01-02 16ABB	865	862	-2.6
B-01-02 16BBB	852	861	8.5
B-01-02 17CAA	858	860	1.7
B-01-02 17CBB	857	858	1.4
B-01-02 18ACC	851	857	6.4
B-01-02 18ADA	851	858	6.8
B-01-02 18ADB	856	858	1.7
B-01-02 20ABA	863	861	-2.0
B-01-02 20CBA	861	858	-2.5
B-01-02 20DAA1	863	861	-2.3
B-01-02 20DAA2	863	860	-2.6
B-01-02 21ABB	855	863	7.8
B-01-02 21BCC	865	862	-3.4
B-01-02 21CBA	864	862	-2.1
B-01-02 21DCA3	863	863	-0.4
B-01-02 22DBA1	870	869	-1.3
B-01-02 22DBA2	869	868	-0.8
B-01-02 22DBB	870	867	-2.7
B-01-02 22DCC	868	867	-1.0
B-01-02 23AAB1	872	871	-0.6
B-01-02 23BCB2	870	869	-0.8
B-01-02 23CAD2	870	870	0.4
B-01-02 24AAA2	871	872	1.2
B-01-02 24ADD	883	874	-9.3
B-01-02 25DBA2	881	871	-9.8
B-01-02 26BCB	867	867	0.2
B-01-02 26BDC	871	866	-4.6
B-01-02 26CCC	866	864	-2.0
B-01-02 27CAA	863	865	1.9
B-01-02 28CBD	865	859	-5.9
B-01-02 29DCA	863	856	-6.7

APPENDIX TABLE C-1

ADWR MODEL UNWEIGHTED CALIBRATION RESIDUALS - WSRV SUBBASIN

B-02-01 31ABB2	860	860	0.2
B-02-01 31CAA2	863	867	4.2
B-02-01 32BBA	870	865	-4.6
B-02-01 32CBB	871	870	-0.9
B-02-01 34CAA2	887	873	-14.3
B-02-01 34DDA	889	873	-15.7
B-02-01 35DAA	895	878	-16.8
B-02-01 36BAA	867	878	11.1
B-02-01 36BBC	875	876	1.3
B-02-01 36CBA2	914	883	-31.1
B-02-02 01AAA	751	786	34.7
B-02-02 01ABA	771	786	15
B-02-02 01BBB	783	797	14.4
B-02-02 02ADD1	776	797	21
B-02-02 03BBB	836	820	-15.5
B-02-02 04DCB	838	823	-15.1
B-02-02 05AAB	827	819	-7.5
B-02-02 10DCC	797	824	27.4
B-02-02 11BBB	786	809	23.4
B-02-02 12BBB	775	795	19.8
B-02-02 13ABB	782	796	14.1
B-02-02 13BBA	782	793	10.5
B-02-02 14ABB	779	807	28.3
B-02-02 14BCC	802	823	21.2
B-02-02 15AAA	789	816	27.5
B-02-02 16ABB	805	831	25.8
B-02-02 17DDD	830	837	7.2
B-02-02 20DDD2	818	851	32.9
B-02-02 21BDD	833	848	14.9
B-02-02 22AAA	815	829	14.5
B-02-02 22ABB	820	835	14.8
B-02-02 22BBB	815	838	23.2
B-02-02 24CBB3	803	824	20.9
B-02-02 24CCC	814	835	21.1
B-02-02 24DBB2	804	824	19.9
B-02-02 25AAA3	826	837	10.6
B-02-02 25ABB2	819	836	16.6
B-02-02 25CAA	833	849	15.8
B-02-02 25CBB2	832	848	15.5
B-02-02 25DAA2	838	849	10.8
B-02-02 34BAA	842	855	13.3
B-02-02 35BBB	847	855	8.3
B-02-02 36BBB3	845	859	13.8
B-02-02 36CAA	863	860	-3.4
B-03-01 02ACC	780	819	38.9
B-03-01 03BBB	776	827	50.8
B-03-01 05ABB	833	830	-2.6
B-03-01 06BAA	802	835	33.2
B-03-01 06BCB	830	839	8.9
B-03-01 08ACC	782	811	28.5
B-03-01 09CDD	822	803	-19.2
B-03-01 09DBB	768	811	43.3
B-03-01 11BBB	779	820	40.6
B-03-01 14AAA	721	822	100.6
B-03-01 15BBB3	756	813	57
B-03-01 15CBB1	831	808	-22.7
B-03-01 15CBB3	764	810	45.5
B-03-01 16BBB1	709	796	87.4
B-03-01 16DAB	830	803	-27
B-03-01 16DBB1	844	797	-46.7
B-03-01 16DBB2	730	797	66.9
B-03-01 17DCC	741	811	70
B-03-01 19CBB	810	816	6.5
B-03-01 22BAD	809	819	10.4
B-03-01 22BBB2	747	813	66
B-03-01 22CBA	837	816	-21.2
B-03-01 23BBB1	844	826	-17.6
B-03-01 24BBB3	764	828	64.2
B-03-01 26ABB	747	829	82.2
B-03-01 26BAB	708	822	113.9
B-03-01 26BBB	717	815	98.5
B-03-01 26CBB2	707	817	110.4
B-03-01 27ABB1	710	810	100.2
B-03-01 27BBB	828	810	-18
B-03-01 29AAB	791	807	16
B-03-01 29BBB	782	800	17.9
B-03-01 29BCC	755	799	43.7
B-03-01 31BCC	764	785	20.6
B-03-01 32BAA	779	798	18.7
B-03-01 32BAD	746	795	49.2
B-03-01 32CBA	781	796	15.4
B-03-01 34DBB1	823	813	-10.3
B-03-01 35BBB	715	820	104.8
B-03-02 01BBB	788	840	51.8
B-03-02 02BAA	843	847	4.4
B-03-02 02CBC	827	849	21.8
B-03-02 03BAA	885	863	-21.8
B-03-02 03CBA	889	860	-29.4
B-03-02 11BAA	815	842	26.6
B-03-02 12AAA	845	836	-8.8
B-03-02 12BAA	845	838	-7.1
B-03-02 14BAA	825	832	7
B-03-02 14BCB2	854	830	-23.9
B-03-02 15AAA	843	835	-8.3
B-03-02 21ABA	925	837	-87.6
B-03-02 22AAA	836	828	-8.2
B-03-02 23AAA	819	822	2.8
B-03-02 23BAA	796	825	28.5
B-03-02 25BAA	780	809	29.2
B-03-02 25BBB	837	813	-23.9
B-03-02 26BAA	813	818	4.7
B-03-02 26CDD	799	811	11.8
B-03-02 27AAA	815	820	5.2
B-03-02 27ABB	824	823	-1.4
B-03-02 34BAA	819	818	-0.7
B-03-02 35BBB	806	813	7.4
B-03-02 36ABB	772	791	18.6
B-04-01 09BCD	922	876	-46.4
B-04-01 12BCB	927	887	-40
B-04-01 14BBB	888	850	-38.3
B-04-01 18BAA	861	887	25.6
B-04-01 19BBA	837	864	26.8
B-04-01 19BDC	829	854	25.5
B-04-01 21BAA	822	838	15.7
B-04-01 21BBB	808	840	32.2
B-04-01 22ABB	846	838	-8.2
B-04-01 23BBB	850	840	-10.2
B-04-01 23CAB	843	839	-4.4
B-04-01 24DBB	839	849	9.6
B-04-01 27CBB	793	829	36.2

B-01-02 29CCC	857	861	3.7
B-01-02 32DCB	857	857	-0.4
B-01-02 34ABB	865	861	-4.1
B-01-02 36BBC	876	869	-7
B-01-02E19ABB2	862	863	1.3
B-01-03 14AAB	836	861	25.4
B-01-03 14DBB	842	861	19.5
B-01-03 19CBB	862	871	8.5
B-01-03 20CAA	850	861	10.9
B-01-03 21DBB	847	862	15.1
B-01-03 23ACB	842	860	18.5
B-01-03 23CBB	848	860	12.3
B-01-03 27CBB	853	856	2.6
B-01-03 28CBB	852	855	3.1
B-01-03 29BAA	856	859	2.6
B-01-03 30AAA	857	858	0.9
B-01-03 30BAA	849	862	12.9
B-01-03 31BCB	850	845	-5.1
B-01-03 32BAA	850	850	0.4
B-01-03 34BBB1	853	852	-0.7
B-01-03 34CAD	850	847	-3.1
B-01-03 35BDD2	851	851	-0.1
B-01-03 36AAB	858	858	0.3
B-01-03 36BBD	854	855	0.6
B-01-04 16DBA	877	908	31.2
B-01-04 16DCD	877	899	21.9
B-01-04 19BAA	925	918	-6.9
B-01-04 19BBB1	925	921	-3.6
B-01-04 19BBB2	923	919	-3.9
B-01-04 20CBA	943	897	-46.3
B-01-04 20DDA2	943	892	-51.1
B-01-04 21CDD	892	885	-7.3
B-01-04 24AAA	846	852	6.4
B-01-04 25DBC	847	851	3.7
B-01-04 26BAA	858	864	6
B-01-04 27AAD	856	864	7.9
B-01-04 27ABB	866	869	2.6
B-01-04 27DBC	858	857	-0.8
B-01-04 28DAA	865	866	1.3
B-01-04 29AAA	944	888	-56.3
B-01-04 29ACC	890	879	-11.4
B-01-04 31BCD	852	866	14.2
B-01-04 32ABA	862	867	5.5
B-01-04 32BBB2	856	870	13.8
B-01-04 32DAA	854	857	3.3
B-01-04 33BDA	855	857	2.2
B-01-04 34BBA	852	853	0.7
B-01-04 34BCD	846	848	1.5
B-01-04 35AAD	823	844	20.6
B-01-04 35ACB2	836	844	7.6
B-01-04 35BBC	849	847	-2.2
B-01-04 36BBB	853	846	-6.6
B-01-04 36CBB	844	842	-2
B-01-05 24ADB	929	918	-11.5
B-01-05 35DAA2	855	873	17.9
B-01-05 36AAA	858	879	20.8
B-01-05 36CCB	840	866	26.5
B-02-01 01CCC2	869	852	-17
B-02-01 01CCC3	842	853	11
B-02-01 04DCB	700	813	112.9
B-02-01 05AAB	715	800	84.8
B-02-01 05ABC2	718	796	77.8
B-02-01 05ABD	781	799	17.9
B-02-01 05DBB	728	796	67.8
B-02-01 06ABB3	758	779	21
B-02-01 06BCB2	724	783	59.4
B-02-01 06DBB1	758	781	22.6
B-02-01 06DBB3	760	781	21.5
B-02-01 07ABB	758	786	28.4
B-02-01 07CAD	761	792	31
B-02-01 07CBB1	755	787	31.9
B-02-01 08ADC	761	805	44.2
B-02-01 08CAD	745	802	57.3
B-02-01 08CDC	754	804	50.1
B-02-01 08DAB	761	806	44.8
B-02-01 09BCB1	721	809	87.8
B-02-01 09BCB2	704	797	93.4
B-02-01 09BDC	689	814	125.3
B-02-01 09CCC	706	816	110.4
B-02-01 12BAC	899	859	-40.2
B-02-01 12BDD3	871	859	-12.3
B-02-01 12CAD	881	860	-21.2
B-02-01 12CDD	879	862	-16.6
B-02-01 13BAD	880	864	-15.6
B-02-01 13CCA	887	866	-20.6
B-02-01 14AAD	872	859	-13.3
B-02-01 14ABD2	853	858	4.6
B-02-01 18BBB2	759	790	30.7
B-02-01 18CBB2	759	793	34.4
B-02-01 19AAB2	789	808	18.9
B-02-01 19BAA	788	803	15.5
B-02-01 19BBB2	769	799	29.5
B-02-01 20BCC	795	824	28.7
B-02-01 23DBB	838	863	24.7
B-02-01 23DCB	841	864	22.7
B-02-01 23DCC	840	865	25.5
B-02-01 24BBD	875	864	-11.5
B-02-01 25ADC	891	877	-13.8
B-02-01 25BBB	844	866	21.6
B-02-01 26AAA	853	865	12.1
B-02-01 26ACA	871	868	-3.2
B-02-01 26CBC2	879	872	-7.1
B-02-01 27CBC	885	868	-16.5
B-02-01 27DCC	888	874	-13.9
B-02-01 29BAB	837	842	4.8
B-02-01 30CAA2	821	841	20.3
B-02-01 31BBA2	832	850	18.4
B-02-01 31CAA2	854	864	9.6
B-02-01 32AAA2	869	864	-4.8
B-02-01 32CBB	868	868	-0.5
B-02-01 33BCC2	884	872	-12.3
B-02-01 34CAA2	890	878	-11.9
B-02-01 34DDA	896	881	-14.9
B-02-01 36BAA	892	881	-10.6
B-02-01 36BBC	895	881	-13.8
B-02-01 36CBB	902	884	-17.8
B-02-01 36CDD	910	890	-20.1
B-02-02 01ABA	737	772	34.5
B-02-02 03AAA	764	791	26.9
B-02-02 03BBB	825	805	-20.1

B-01-02 30ABB	859	855	-3.9
B-01-02 30ACC	863	855	-8.4
B-01-02 30DCC	856	853	-3.3
B-01-02 31DBC	855	850	-5.5
B-01-02 31DCC1	851	848	-3.0
B-01-02 31DCC2	853	848	-5.2
B-01-02 32ADD	861	857	-4.4
B-01-02 32CCD	854	851	-3.0
B-01-02 32DCB	856	853	-3.1
B-01-02 35BAA2	867	866	-1.0
B-01-02 36BBC	873	868	-4.9
B-01-02E19ABB2	858	857	-0.8
B-01-02E19ABB3	856	857	1.0
B-01-03 14AAB	829	854	24.8
B-01-03 20CAA	848	851	2.6
B-01-03 21DBB	839	852	13.2
B-01-03 23ACB	839	853	13.6
B-01-03 23CBB	843	852	8.5
B-01-03 24CBB2	851	853	2.2
B-01-03 25BBC2	853	852	-0.6
B-01-03 27CBB	849	848	-0.6
B-01-03 28CBB	849	846	-2.9
B-01-03 29BAA	851	848	-3.0
B-01-03 30AAA	852	846	-6.5
B-01-03 30BAA	846	844	-2.3
B-01-03 31BCB	846	834	-12.3
B-01-03 31DBA	847	836	-11.0
B-01-03 32BAA	846	841	-4.7
B-01-03 34ADD2	848	843	-4.5
B-01-03 34BBB1	847	846	-0.7
B-01-03 34CCB	844	842	-1.8
B-01-03 35ACB	846	846	-0.3
B-01-03 35BDD2	851	845	-6.2
B-01-03 36AAB	855	852	-2.7
B-01-03 36BBD	850	848	-2.5
B-01-04 16DBA	870	906	36.3
B-01-04 19AAA	927	912	-15.1
B-01-04 19BAA	924	918	-6.5
B-01-04 19BBB1	928	921	-6.8
B-01-04 19BBB2	930	918	-12.1
B-01-04 20CBA	939	885	-54.3
B-01-04 20DDA2	934	875	-59.3
B-01-04 24AAA	846	844	-2.2
B-01-04 25DBC	839	836	-3.3
B-01-04 26BAA	850	847	-3.2
B-01-04 27AAD	849	846	-2.7
B-01-04 27ABB	858	851	-6.9
B-01-04 27DBC	851	841	-9.9
B-01-04 28DAA	857	849	-8.4
B-01-04 29AAA	936	868	-68.1
B-01-04 31BCD	846	851	5.4
B-01-04 32BBB2	840	853	12.8
B-01-04 32DAA	846	841	-4.5
B-01-04 33BDA	847	841	-6.0
B-01-04 34BBA	847	837	-9.9
B-01-04 34BCD	841	834	-7.2
B-01-04 35AAD	826	831	5.1
B-01-04 35ACB2	808	832	23.6
B-01-04 35BBC	845	834	-11.5
B-01-04 36BBB	848	833	-15.2
B-01-05 35ABA	855	881	26.2
B-01-05 35DAA2	849	866	16.7
B-01-05 36AAA	853	865	12.1
B-02-01 01CCC2	857	841	-16.0
B-02-01 04DAA	771	786	15.5
B-02-01 05AAB	702	759	57.5
B-02-01 05ABC2	736	756	19.9
B-02-01 05ABD	756	756	0.2
B-02-01 05DBB	709	759	49.9
B-02-01 06BCB2	659	749	90.2
B-02-01 06DBB2	727	745	17.9
B-02-01 08ADA	736	778	41.8
B-02-01 08ADC	739	778	39.1
B-02-01 08CAD	728	777	48.7
B-02-01 08CDB	733	777	43.8
B-02-01 09BCB1	696	781	84.8
B-02-01 09CCC	686	794	108.2
B-02-01 12BAC	911	852	-59.3
B-02-01 12BDD3	878	852	-25.8
B-02-01 12CAD	873	854	-18.8
B-02-01 12CDD	879	858	-21.3
B-02-01 13BAD	878	861	-17.2
B-02-01 14ABD2	800	849	49.3
B-02-01 18CBB2	723	764	40.9
B-02-01 19BBB2	731	771	39.5
B-02-01 19DBB2	770	789	18.6
B-02-01 20BCC	772	801	28.9
B-02-01 23DBB	852	865	12.7
B-02-01 23DCB	844	866	22.0
B-02-01 23DDD	846	868	22.2
B-02-01 24BBD	872	865	-7.2
B-02-01 25ACA	879	882	3.3
B-02-01 25BBB	852	870	18.3
B-02-01 25BCB	874	873	-1.1
B-02-01 26ACA	871	871	0.0
B-02-01 26CBC2	877	872	-5.3
B-02-01 27CBC	887	868	-18.8
B-02-01 27DCC	887	874	-12.9
B-02-01 30CAA2	803	821	18.1
B-02-01 31ABB2	833	836	3.2
B-02-01 32AAA2	881	858	-23.0
B-02-01 32BBA	865	848	-17.0
B-02-01 32CBB	860	858	-2.4
B-02-01 33BCC2	886	870	-15.5
B-02-01 33BDD2	888	873	-15.0
B-02-01 34CAA2	889	879	-10.0
B-02-01 34DDA	894	883	-11.3
B-02-01 35AAB	891	881	-10.4
B-02-01 35ABD	895	882	-13.0
B-02-01 36ACD	905	896	-8.9
B-02-01 36BAA	895	887	-7.5
B-02-01 36BBA3	891	882	-8.7
B-02-01 36CDD	911	896	-14.7
B-02-02 02BAD	730	759	28.7
B-02-02 02BBC	741	767	25.5
B-02-02 03AAA	748	765	17.5
B-02-02 03BAA	761	775	13.8
B-02-02 03BBB	821	782	-38.8
B-02-02 04DCB	840	786	-54.4
B-02-02 05AAB	827	796	-31.4

APPENDIX TABLE C-1

ADWR MODEL UNWEIGHTED CALIBRATION RESIDUALS - WSRV SUBBASIN

B-04-01 28BAA	801	833	32.2
B-04-01 28DBD	794	827	33.1
B-04-01 29ADC	795	833	37.9
B-04-01 29BCA	809	836	26.5
B-04-01 29DBB	799	832	32.9
B-04-01 30DCD	799	838	38.5
B-04-01 32BBC	794	834	40.4
B-04-01 32BDA	797	832	35.3
B-04-01 33ACC	784	826	41.9
B-04-01 33BAB	788	828	39.9
B-04-01 33BDB	788	827	38.7
B-04-01 34ACB	788	826	37.6
B-04-01 34CBB	777	826	48.9
B-04-02 11BDB	1066	974	-92.2
B-04-02 16AAD	1082	996	-86.3
B-04-02 24BCD	844	873	29
B-04-02 25BAA	826	857	30.8
B-04-02 26ABA	849	873	24.2
B-04-02 26DBB	856	865	9.4
B-04-02 26DDD	833	850	16.7
B-04-02 27DCD	875	878	2.7
B-04-02 34BBA	958	887	-70.9
B-04-02 34DBA	871	865	-6
B-04-02 35BDD	782	852	70.1
B-04-02 35CBB	824	858	34.1
B-04-02 35CCC	859	853	-6.1
B-04-02 36BAA	818	843	25
B-04-03 28DDD	1216	1166	-49.9
B-05-02 08CCB	1182	1194	11.7
B-05-02 13CAA	1067	1129	61.9
B-05-02 13CDB	1063	1126	63.1
B-05-02 15CCB	1115	1154	38.8
B-05-02 17ABD	1154	1181	27.2
B-05-02 23DCA	1078	1114	35.9
B-05-02 24BAB	1066	1124	57.9
B-05-02 24BAD	1062	1121	58.6
B-05-02 24CAD1	1067	1109	42.3
B-05-02 24CAD3	1062	1111	48.9
B-05-02 26BBA	1122	1112	-9.6
B-05-02 35BAA	1092	1071	-21.3
B-05-03 13BCA2	1202	1206	3.6
B-05-03 15AAA	1228	1228	0.4
B-05-03 22ADD	1225	1218	-6.9
B-05-03 23ABB	1218	1212	-6.2
B-05-03 30BAA	1295	1265	-30.1
B-06-02 31BDD	1206	1223	17.2
B-06-03 29CBC	1331	1300	-31.4
B-06-03 33DCB	1253	1268	15.3
B-06-03 36DDD	1207	1225	18.4
C-01-02 04BAC	853	843	-10.1
C-01-02 04BBD	855	843	-12.3
C-01-02 05BAD	851	835	-16.4
C-01-02 06ADD	848	831	-16.9
C-01-02 06CAD	850	832	-18
C-01-02 08CDA	835	837	2.3
C-01-02 18ACA	843	836	-6.8
C-01-02 19ACC	843	837	-6
C-01-02 19ACD1	846	837	-8.8
C-01-03 01ADD	848	829	-18.6
C-01-03 01BDD2	847	830	-17.2
C-01-03 02DAD	846	832	-14
C-01-03 04CDD	839	819	-19.6
C-01-03 05AAB	840	837	-2.7
C-01-03 05BAA2	804	838	34.5
C-01-03 06BCB	841	829	-11.7
C-01-03 06BDB	842	833	-9.3
C-01-04 01BDD1	837	824	-12.8
C-01-04 02CBC	835	819	-15.5
C-01-04 02DBB2	834	819	-14.8
C-01-04 03ABB	843	844	1.3
C-01-04 03BDA	840	838	-2.2
C-01-04 03DCB	835	826	-9.3
C-01-04 04ADA	844	844	0.5
C-01-04 04CDD	827	834	7.4
C-01-04 05BAB	834	855	21.1
C-01-04 05CAA	834	848	13.7
C-01-04 06BBA	843	861	17.8
C-01-04 06DBC	838	848	10.1
C-01-04 07BDD	823	844	21.1
C-01-04 08BBA	832	841	9
C-01-04 08BCB	831	841	10.2
C-01-04 09BCB2	832	835	3.5
C-01-04 15CBB	775	800	24.9
C-01-04 17DCB	808	803	-4.9
C-01-04 18AAA	820	828	7.7
C-01-04 18BAA	815	833	17.8
C-01-04 18DAA	811	816	4.6
C-01-04 19AAA1	800	802	1.6
C-01-04 27BBC1	792	788	-3.5
C-01-04 27BDC	792	789	-3.1
C-01-05 01DCC	833	853	20
C-01-05 03BAA1	838	862	24.5
C-01-05 03BAB2	838	860	22.4
C-01-05 10ABB	809	842	32.8
C-01-05 13AAB	813	836	23.1
D-01-01 02BBC	942	950	7.5
D-01-01 03ADD	954	951	-3.3
D-01-01 13DDD1	977	962	-14.7
D-01-02 02DCC2	1014	978	-36.4
D-01-02 03CBA	980	971	-9.3
D-01-02 06ADD	957	952	-4.9
D-01-02 06DDD	965	956	-9.1
D-01-02 07ADD	984	959	-25.5
D-01-02 07CBA	976	959	-17
D-01-02 07DCC	974	959	-14.8
D-01-02 08BAA1	971	962	-9.3
D-01-02 10BBB	995	967	-28
D-01-02 17ADC	992	966	-26.4
D-01-02 17CDD	975	964	-11.2
D-01-02 18ADD	984	963	-21.2
D-01-02 18DCD	978	963	-14.8
D-01-02 19DAA	982	966	-16.1
D-01-02 20BDA	988	965	-23.4
D-01-02 20CDD	987	971	-16.3
D-01-02 20DCB	985	968	-17.3
D-01-02 28CBC	999	979	-19.9
D-01-02 29BDD	989	975	-13.7
D-01-03 06AAA	1017	988	-29.4
D-01-03 06DBB	1024	988	-35.9

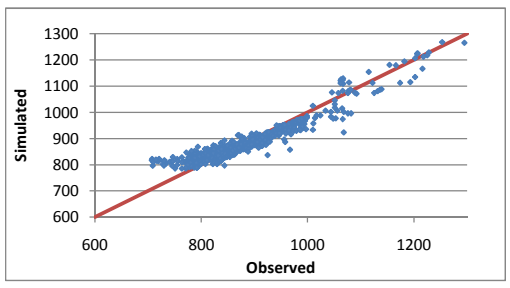
B-02-02 04DCB	836	808	-28
B-02-02 05AAB	842	807	-34.7
B-02-02 10BAA	750	804	53.6
B-02-02 10DCC	766	812	46.3
B-02-02 11BBB	755	796	41.1
B-02-02 13ABB	756	790	34.3
B-02-02 13BBA	756	791	35.2
B-02-02 14ABB	755	798	43.3
B-02-02 16ABB	770	815	44.5
B-02-02 17DDD	781	820	38.8
B-02-02 20DDD2	784	840	56.2
B-02-02 21ABB	734	821	86.6
B-02-02 22AAA	787	817	29.7
B-02-02 22ABB	793	823	29.7
B-02-02 22BBB	784	824	39.8
B-02-02 24BAA	762	796	34.3
B-02-02 24CCC	784	822	37.7
B-02-02 24DBB2	770	808	38.4
B-02-02 25AAA2	798	823	24.9
B-02-02 25ABB2	781	821	40.1
B-02-02 25CBB2	786	834	48
B-02-02 25DAA2	815	836	21.2
B-02-02 26AAA	787	824	36.5
B-02-02 27AAA	810	832	22.1
B-02-02 27CCC	826	850	24.4
B-02-02 28AAA	810	840	29.8
B-02-02 28ABB	795	843	48.1
B-02-02 34BAA	823	851	27.6
B-02-02 36BBB3	813	845	31.8
B-02-02 36BCC	815	855	39.6
B-02-02 36CAA	848	856	7.6
B-03-01 02ACC	776	828	51.9
B-03-01 05ABB	826	826	0.1
B-03-01 06BAA	797	825	27.9
B-03-01 07ABB	806	810	4
B-03-01 08ABB1	883	806	-77.3
B-03-01 08CBC	784	798	13.6
B-03-01 09CDD	826	797	-28.9
B-03-01 09DBB	757	806	49.2
B-03-01 11BBB	804	814	10.3
B-03-01 13BAA2	660	829	169.4
B-03-01 14AAA	738	825	87.1
B-03-01 15BBB2	806	799	-7.4
B-03-01 15BBB3	735	803	67.6
B-03-01 15CBB1	820	799	-20.8
B-03-01 15CBB3	729	807	77.8
B-03-01 16BBB1	739	788	48.7
B-03-01 16BCC	736	790	54.3
B-03-01 16DAB	723	795	71.8
B-03-01 16DBB1	845	789	-56.5
B-03-01 16DBB2	739	788	49.3
B-03-01 16DBB3	723	788	65.4
B-03-01 19CBB	796	791	-5
B-03-01 22ABB	691	815	124.1
B-03-01 22BCA	789	813	24.1
B-03-01 23BBB1	828	820	-7.6
B-03-01 23BBC	745	821	76
B-03-01 24BBB3	783	832	48.7
B-03-01 26ABB	752	833	81.1
B-03-01 26BAB	704	830	125.5
B-03-01 26BBB	722	828	106.5
B-03-01 26CBB2	701	830	128.5
B-03-01 27ABB1	693	821	127.6
B-03-01 27ABC2	698	820	122.2
B-03-01 29BCC	739	791	52.4
B-03-01 31BCC	727	774	46.8
B-03-01 32BAD	717	791	73.9
B-03-01 34DBB1	794	821	26.8
B-03-01 35BBB	640	829	189.1
B-03-02 01BBB	728	833	104.5
B-03-02 02BAA	859	836	-22.9
B-03-02 02CBC	853	829	-24
B-03-02 03BAA	868	849	-19.4
B-03-02 10BBA	849	830	-18.8
B-03-02 10BDC	850	826	-24
B-03-02 11BAA	826	816	-9.8
B-03-02 12AAA	810	802	-7.7
B-03-02 12BAA	800	806	6.2
B-03-02 13BAA	838	794	-43.7
B-03-02 14BAA	809	803	-6.3
B-03-02 14BCB2	822	805	-17
B-03-02 15AAA	816	806	-9.5
B-03-02 21ABA	915	823	-92.5
B-03-02 22AAA	809	801	-7.8
B-03-02 23BAA	798	798	-0.4
B-03-02 25BAA	750	787	36.9
B-03-02 26BAA	787	795	7.9
B-03-02 27AAA	793	798	4.6
B-03-02 27ABB	802	803	1.5
B-03-02 35AAA	750	781	31.2
B-03-02 35BBB	775	792	16.6
B-03-02 35CBB	784	788	4.1
B-03-02 36ABB	733	776	43.1
B-04-01 09BCD	936	892	-44.2
B-04-01 18BAA	871	896	25.2
B-04-01 19BBA	844	874	29.7
B-04-01 19BDC	839	863	23.7
B-04-01 21BAA	832	851	18.9
B-04-01 22ABB	887	852	-34.9
B-04-01 23BBB	864	854	-9.9
B-04-01 23CAB	844	852	8.2
B-04-01 27CBB	808	840	32.3
B-04-01 28BAA	808	845	37.4
B-04-01 29ADC	804	842	38.1
B-04-01 30ABB	912	854	-58
B-04-01 30DCD	802	837	35.1
B-04-01 32BBC	798	833	35.2
B-04-01 34ACB	799	837	38.4
B-04-01 34CBB	784	834	50
B-04-01 34DBB	793	836	43.4
B-04-02 05DBB	1151	1111	-40.1
B-04-02 10BCA	1104	1033	-70.9
B-04-02 11BDB	1071	982	-89.2
B-04-02 14CCA	1016	933	-82.5
B-04-02 16AAD	1087	1004	-83
B-04-02 24BCD	846	878	31.9
B-04-02 25BAA	830	863	32.5
B-04-02 26ABA	843	874	31.1
B-04-02 26DCB	831	853	22.1
B-04-02 26DDD	832	848	15.8

B-02-02 10BAA	735	778	43.2
B-02-02 10DCC	739	785	45.5
B-02-02 11BBB	726	769	42.9
B-02-02 13BBA	711	752	40.5
B-02-02 17DDD	795	795	-0.3
B-02-02 21ABB	764	799	34.9
B-02-02 22ABB	765	797	31.7
B-02-02 22BBB	763	800	36.7
B-02-02 24BAA	722	769	47.3
B-02-02 24BBB3	731	771	40.4
B-02-02 24DBB2	733	780	47.1
B-02-02 25AAA2	765	797	32.4
B-02-02 25CAA	720	806	86.2
B-02-02 25CBB2	780	810	30.4
B-02-02 25DAA2	787	813	26.1
B-02-02 26AAA	733	796	63.0
B-02-02 27AAA	776	809	32.6
B-02-02 27CCC	802	834	32.1
B-02-02 28DBB	813	829	15.6
B-02-02 32CBA	831	840	9.1
B-02-02 34BAA	828	833	4.5
B-02-02 35BBB	814	831	17.2
B-02-02 36CAA	822	840	18.4
B-03-01 02DAD	766	822	55.9
B-03-01 03BBB	758	823	65.4
B-03-01 06BAA	808	815	6.5
B-03-01 08ABB1	865	782	-82.7
B-03-01 08ABB2	787	789	2.0
B-03-01 08ACC	782	770	-11.7
B-03-01 08CBC	800	768	-32.1
B-03-01 09CDD	814	767	-47.1
B-03-01 11BBB	771	803	31.8
B-03-01 12CBB1	735	818	82.6
B-03-01 13BAA2	767	824	56.7
B-03-01 15BBB3	754	771	16.5
B-03-01 15CBB3	738	776	38.0
B-03-01 16DAB	752	757	4.8
B-03-01 17DBB2	736	754	18.1
B-03-01 19CBB	776	756	-19.8
B-03-01 20BBB1	771	750	-20.8
B-03-01 23BBC	752	789	37.3
B-03-01 24BBB3	781	816	34.7
B-03-01 25BBB3	796	823	27.1
B-03-01 26ABB	746	808	62.3
B-03-01 26BAB	707	801	94.0
B-03-01 26CBB2	704	792	87.7
B-03-01 27ABB2	705	773	68.3
B-03-01 27ABC2	710	773	63.3
B-03-01 27BBB	788	769	-19.2
B-03-01 29BCC	720	750	30.2
B-03-01 31BCC	718	736	18.3
B-03-01 32BAA	733	754	20.9
B-03-01 32BAD	718	751	32.8
B-03-01 34BBB	710	778	67.7
B-03-01 34DBB1	777	789	11.6
B-03-01 35BBB	710	797	86.8
B-03-02 01BBB	833	825	-7.8
B-03-02 02CBC	849	822	-26.6
B-03-02 03BAA	876	844	-31.5
B-03-02 10BDC	851	817	-34.4
B-03-02 11BAA	838	807	-31.5
B-03-02 14BCB2	819	783	-35.5
B-03-02 25BAA	746	758	11.5
B-03-02 26BAA	772	768	-3.6
B-03-02 26CDD	777	764	-12.6
B-03-02 34BAA	780	777	-3.2
B-03-02 35AAA	736	756	19.6
B-03-02 35BBB	769	769	0.0
B-03-02 35CBB	778	766	-11.6
B-04-01 14BBB	910	884	-26.3
B-04-01 18BAA	877	905	28.3
B-04-01 18CBD	866	890	24.1
B-04-01 19BBA	902	882	-20.5
B-04-01 20BCB	838	868	30.2
B-04-01 23DBA	861	866	5.0
B-04-01 24DBB	870	870	-0.2
B-04-01 29ABB	820	856	35.6
B-04-01 30ABB	828	860	32.5
B-04-01 30BCD	996	855	-141.2
B-04-01 33CBB	800	828	28.5
B-04-01 34CBB	778	829	51.1
B-04-02 10BCA	1109	1047	-62.0
B-04-02 11BDB	1078	994	-84.3
B-04-02 14CCA	1025	940	-84.6
B-04-02 16AAD	1091	1015	-75.9
B-04-02 24BCD	852	884	32.0
B-04-02 25BAA	842	867	25.0
B-04-02 26DBB	865	866	0.6
B-04-02 27DCD	860	866	5.8
B-04-02 34DBA	875	851	-24.1
B-04-02 36BCB	846	841	-5.4
B-04-03 04BDB	1236	1219	-17.3
B-04-03 14ABA	1192	1156	-36.4
B-04-03 15DAC	1199	1165	-33.6
B-04-03 19DBA	1223	1217	-5.8
B-04-03 28DDD	1216	1159	-56.9
B-05-02 24BAB	1074	1131	56.9
B-05-02 26DDD	1064	1082	17.6
B-05-02 30ADD	1178	1175	-2.8
B-05-02 35BAA	1104	1088	-16.2
B-05-03 15AAA	1229	1224	-4.6
B-05-03 21DDA	1245	1228	-17.2
B-05-03 22ADD	1221	1217	-3.6
B-05-03 23ABB	1220	1211	-8.7
B-05-03 33BCB	1249	1232	-17.2
B-06-02 30ADB	1316	1225	-91.4
C-01-02 08CDA	841	845	4.2
C-01-02 18ACA	851	844	-7.4
C-01-02 19ACD1	857	843	-14.4
C-01-02 19ACD3	854	843	-11.5
C-01-03 01ADD	846	843	-2.9
C-01-03 01BDD2	850	840	-9.9
C-01-03 02DAD	847	837	-10.4
C-01-03 04CDD	839	821	-18.2
C-01-03 05AAB	838	836	-2.2
C-01-03 06BCB	836	824	-11.6
C-01-03 06BDB	838	828	-10.2
C-01-03 13ABC	851	839	-11.9
C-01-03 13BBC	837	836	-0.6
C-01-03 13CBD	841	839	-2.1

APPENDIX TABLE C-1

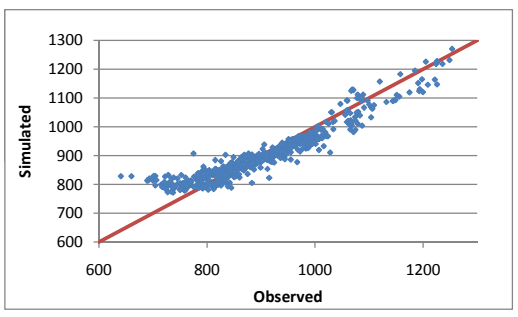
ADWR MODEL UNWEIGHTED CALIBRATION RESIDUALS - WSRV SUBBASIN

Mean Error	*-0.12*
Abs Mean	*22.09*
RMSE	*29.83*



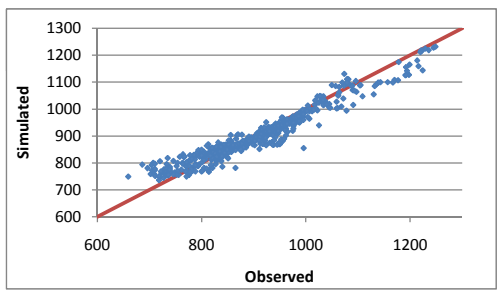
B-04-02 27DCD	867	869	1.9
B-04-02 34BBA	967	878	-88.6
B-04-02 34DBA	845	854	8.5
B-04-02 35CCC	829	839	10.2
B-04-02 36BAA	818	843	25.2
B-04-03 04BDB	1236	1218	-18
B-04-03 14ABA	1191	1152	-39
B-04-03 15DAC	1198	1165	-32.5
B-04-03 19DBA	1226	1223	-3.3
B-04-03 28DDD	1222	1164	-57.8
B-05-02 08CCB	1185	1195	9.9
B-05-02 13CDB	1069	1130	61.1
B-05-02 15CCB	1120	1157	36.9
B-05-02 17ABD	1158	1183	25.4
B-05-02 24BAB	1071	1128	57
B-05-02 24BAD	1067	1125	58
B-05-02 35BAA	1100	1078	-22.2
B-05-03 15AAA	1226	1228	1.8
B-05-03 22ADD	1224	1218	-5.7
B-05-03 33BCB	1249	1232	-17.4
B-06-03 33DCB	1254	1271	17.2
B-06-03 36DDD	1205	1226	20.6
C-01-02 04BBD	861	857	-3.8
C-01-02 05BAD	857	853	-4
C-01-02 06ADD	847	851	3.9
C-01-02 06CAD	851	848	-3.1
C-01-02 18ACA	845	844	-0.9
C-01-02 19ACC	847	841	-5.9
C-01-02 19ACD1	850	841	-8.5
C-01-03 01ADD	853	848	-5.4
C-01-03 01BDD2	844	846	1.8
C-01-03 02DAD	849	843	-6.1
C-01-03 03DAA	842	834	-8
C-01-03 04CDD	840	829	-10.6
C-01-03 05AAB	841	844	2.6
C-01-03 08CBD	820	818	-2.1
C-01-03 13BBC	834	838	3.5
C-01-03 14DAD	841	839	-2.5
C-01-04 01DDA	837	823	-14.1
C-01-04 02CCC	831	813	-18.3
C-01-04 03ABB	843	838	-4.7
C-01-04 03BDA	840	833	-7.1
C-01-04 04ADA	844	838	-6.3
C-01-04 05BAB	837	853	15.6
C-01-04 05CAA	834	844	9.6
C-01-04 06BBA	844	859	14.9
C-01-04 06DBC	842	847	4.6
C-01-04 08BCB	834	837	2.9
C-01-04 08DDD	825	819	-6
C-01-04 09BCB2	834	833	-1.2
C-01-04 10CCC	815	794	-21
C-01-04 11CBC	812	791	-20.7
C-01-04 11DCB	815	793	-22
C-01-04 15ABB1	812	785	-27.4
C-01-04 15ABB2	802	782	-19.9
C-01-04 15CBB	797	794	-2.6
C-01-04 17DCB	812	799	-13.3
C-01-04 18AAA	823	825	1.9
C-01-04 19AAA1	786	799	13.1
C-01-04 24ADA	806	800	-6.3
C-01-04 27BBC1	792	787	-5.2
C-01-04 27BDC	791	788	-3.4
C-01-05 03BAA1	840	862	22.1
C-01-05 13AAB	818	835	17.3
C-01-05 13AAD	817	829	12.5
D-01-01 13DDD1	970	969	-0.6
D-01-02 03CDD	1019	981	-38.1
D-01-02 07CBA	972	966	-6
D-01-02 07DCC	978	968	-9.8
D-01-02 18ADD	988	970	-17.5
D-01-02 18DCD	982	970	-12
D-01-02 19AAA	986	971	-14.8
D-01-02 19DAA	989	973	-15.6
D-01-02 20BDA	993	974	-18.7
D-01-02 20CDD	990	979	-11.2
D-01-02 20DCB	991	977	-14.4
D-01-02 29BDD	991	982	-8.6
D-01-03 04ACC	1031	1051	20.4
D-01-03 06BAD	1033	1016	-16.9
D-01-03 06DBB	1036	1021	-14.7

Mean Error	*-2.34*
Abs Mean	*24.66*
RMSE	*34.02*



C-01-03 14DAD	844	838	-6.0
C-01-04 01BCC	830	820	-9.6
C-01-04 01BDD1	832	820	-12.1
C-01-04 01DDA	835	819	-15.8
C-01-04 02CBC	829	807	-22.1
C-01-04 02DBB2	827	811	-16.1
C-01-04 03ABB	838	826	-11.9
C-01-04 03DCB	828	812	-16.3
C-01-04 04DDA	829	820	-9.1
C-01-04 05BAB	832	837	5.3
C-01-04 05CAA	832	831	-0.8
C-01-04 06BBA	838	846	7.8
C-01-04 07BDD	826	835	8.5
C-01-04 08BCB	831	828	-2.6
C-01-04 08DDD	819	811	-7.6
C-01-04 09BCB2	829	823	-5.9
C-01-04 10BCC	801	803	1.8
C-01-04 10CCC	805	782	-22.6
C-01-04 15ABB1	812	775	-37.4
C-01-04 15ABB2	801	771	-29.8
C-01-04 15ACB1	809	779	-29.9
C-01-04 15CBB	791	790	-0.9
C-01-04 17DAA	788	796	7.5
C-01-04 18AAA	820	820	-0.2
C-01-04 27BBC1	793	789	-3.9
C-01-04 27BDC	794	791	-3.3
C-01-04 27DAA	818	792	-25.6
C-01-05 01AAB	849	850	0.8
C-01-05 01DCC	835	843	8.4
C-01-05 03BAA1	838	861	22.9
C-01-05 03BAB2	837	860	22.7
C-01-05 13AAB	815	832	17.1
C-01-05 13AAD	817	827	9.5
C-01-05 13CDD	804	811	7.2
C-01-05 24CCB	788	792	4.0
D-01-01 13DDD1	956	968	11.7
D-01-01 13DDD2	975	968	-7.3
D-01-02 01DBA	1030	1029	-0.6
D-01-02 03CBA	994	998	4.1
D-01-02 03CDD	1019	1002	-16.6
D-01-02 04ADD	1002	993	-9.1
D-01-02 05ADD	982	980	-2.4
D-01-02 06DDD	975	973	-1.9
D-01-02 07CBA	954	969	14.8
D-01-02 07DCC	975	971	-3.8
D-01-02 10BBB	1015	997	-18.1
D-01-02 18ADD	984	972	-11.8
D-01-02 18DCD	978	970	-8.4
D-01-02 19AAA	982	970	-11.6
D-01-02 20CDD	986	974	-11.5
D-01-03 06AAA	1018	1032	13.6
D-01-03 06BAD	1032	1030	-2.2
D-01-03 06DBB	1033	1034	0.7
D-01-04 05BBB	1167	1099	-67.8

Mean Error	*-4.94*
Abs Mean	*19.31*
RMSE	*27.41*



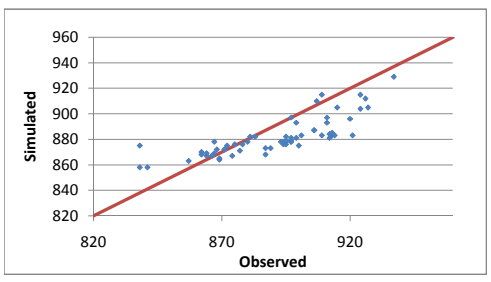
APPENDIX TABLE C-2

ADWR UNWEIGHTED CALIBRATION RESIDUALS - AVONDALE STUDY AREA

2002/2003 Calibration Data (Avondale Study Area)

Local ID	Measured Elevations (ft-amsl)	Simulated Elevations (ft-amsl)	Unweighted Residual (feet)
A-01-01 06CBB1	901	883	-17.7
A-01-01 07CCD	911	893	-18.1
A-01-01 09BBB2	899	893	-6.1
A-01-01 17DAA	927	905	-22.0
A-01-01 19ABB	924	904	-20.4
A-01-01 19DCD1	926	912	-13.7
A-01-01 28CAC	937	929	-7.6
A-01-01 30AAC1	924	915	-9.2
A-01-01 30AAC2	909	915	5.9
A-01-01 30BAA1	907	910	3.2
A-02-01 20BCC2	869	864	-4.8
A-02-01 20CAC	869	865	-3.7
A-02-01 20CCC2	866	867	1.0
A-02-01 20DAA	877	871	-5.8
A-02-01 20DCC	867	869	1.7
A-02-01 20DDD2	871	872	0.9
A-02-01 29CAA2	868	872	3.5
A-02-01 29DDD2	878	876	-1.5
A-02-01 30CAA2	864	867	3.0
A-02-01 30CBB	864	869	5.3
A-02-01 30DAA2	862	868	6.0
A-02-01 30DDD2	871	872	0.5
A-02-01 32DAB2	880	878	-2.4
A-02-01 32DDA	895	879	-15.8
A-02-01 33CCC	881	882	0.8
B-01-01 01CAA	913	883	-29.7
B-01-01 02AAD2	921	883	-37.9
B-01-01 02BBB	894	876	-17.6
B-01-01 03DAB	872	875	3.3
B-01-01 03DBA	900	875	-24.8
B-01-01 04ABA2	838	875	36.7
B-01-01 10AAA2	897	879	-17.5
B-01-01 10BCC	897	878	-19.4
B-01-01 10BDA	893	878	-14.6
B-01-01 10BDB	894	878	-16.4
B-01-01 10CBD	897	878	-18.6
B-01-01 10DDB	883	882	-0.6
B-01-01 11AAA	912	884	-28.0
B-01-01 11BAB	912	881	-30.6
B-01-01 11CCB1	909	883	-25.5
B-01-01 12AAA1	906	887	-19.2
B-01-01 12BAA2	913	885	-27.6
B-01-01 13DBC	920	896	-24.1
B-01-01 15BAD	895	882	-13.1
B-01-01 15CCB	899	881	-18.1
B-01-01 22ACD	906	887	-18.8
B-01-01 24ABB	911	897	-14.1
B-01-01 25BAA	915	905	-10.0
B-01-01 27DAB2	897	897	0.5
B-01-01 28AAB	897	881	-16.2
B-01-01 28CDC	895	876	-19.0
B-02-01 23DDD	841	858	16.9
B-02-01 25ADC	862	870	7.6
B-02-01 25BBB	838	858	19.8
B-02-01 26ACA	857	863	5.8
B-02-01 26CBC2	874	867	-7.4
B-02-01 27CBC	887	868	-19.3
B-02-01 34CAA2	887	873	-14.3
B-02-01 34DDA	889	873	-15.7
B-02-01 35DAA	895	878	-16.8
B-02-01 36BAA	867	878	11.1
B-02-01 36BBC	875	876	1.3
B-02-01 36CBA2	914	883	-31.1

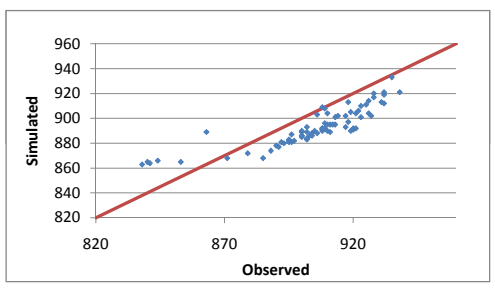
ME	*-9.21*
AME	*13.49*
RMSE	*16.60*



1997/1998 Calibration Data (Avondale Study Area)

Local ID	Measured Elevations (ft-amsl)	Simulated Elevations (ft-amsl)	Unweighted Residual (feet)
B-01-01 28CDC	895	882	-13.0
B-01-01 27DAB2	910	904	-6.1
B-01-01 25ADA	926	914	-11.6
A-01-01 28BCB	935	933	-2.4
A-01-01 30AAC2	932	921	-10.6
A-01-01 30AAC1	928	920	-7.6
B-01-01 25BAA	923	910	-12.6
A-01-01 30BAA1	928	917	-11.3
A-01-01 19DCD1	932	919	-12.8
B-01-01 28ABA	900	889	-11.5
B-01-01 28AAB	902	889	-12.7
B-01-01 22ACD	910	895	-14.8
B-01-01 24ABB	922	906	-16.4
A-01-01 19ABB	931	913	-17.8
B-01-01 15DCA	908	892	-16.0
B-01-01 15CCB	904	888	-16.0
B-01-01 13DBC	926	904	-22.1
A-01-01 17DAA	938	921	-17.3
B-01-01 15BAD	900	890	-10.5
A-01-01 17BBB	932	912	-20.3
B-01-01 10CCD	896	887	-8.5
A-01-01 07CCD	921	904	-17.2
B-01-01 10DCC	863	889	26.1
B-01-01 11CCB1	920	891	-29.0
B-01-01 10DDB	908	890	-18.5
B-01-01 09DDB	900	885	-14.6
B-01-01 10CBB	903	886	-17.3
A-01-01 09BAC	918	913	-4.9
B-01-01 10BDA	900	886	-13.9
B-01-01 11AAA	921	892	-28.7
A-01-01 09BBB2	925	911	-14.1
B-01-01 12AAA1	918	897	-20.8
B-01-01 12BAA2	911	895	-15.8
B-01-01 11AAB	920	892	-28.0
B-01-01 11BAB	919	890	-29.4
B-01-01 10AAA2	906	888	-18.5
B-01-01 03DAC	904	886	-17.8
A-01-01 04CAB	908	909	1.0
A-01-01 06CBB1	913	895	-18.0
B-01-01 01CAA	917	893	-24.0
B-01-01 01BAC	909	892	-17.5
A-01-01 04BAC	909	908	-0.8
B-01-01 04ABA2	893	880	-12.7
B-01-01 03BAA	897	882	-15.0
B-01-01 02BBB	902	883	-18.8
B-02-01 36CDD	910	890	-20.1
A-02-01 33CCC	919	905	-14.0
A-02-01 32DDA	906	903	-3.4
B-02-01 34DDA	896	881	-14.9
B-02-01 36CBB	902	884	-17.8
A-02-01 32DAB2	914	902	-12.4
B-02-01 34CAA2	890	878	-11.9
B-02-01 36BBC	895	881	-13.8
A-02-01 32AAC	913	901	-12.0
B-02-01 36BAA	892	881	-10.6
A-02-01 30DDD2	902	893	-8.9
A-02-01 29DDD2	917	902	-14.7
B-02-01 27DCC	888	874	-13.9
B-02-01 27CBC	885	868	-16.5
B-02-01 26CBC2	879	872	-7.1
A-02-01 30CBB	895	883	-11.9
A-02-01 30DAA2	905	890	-14.9
A-02-01 30CAA2	900	886	-13.6
A-02-01 29CAA2	909	896	-12.7
B-02-01 25ADC	891	877	-13.8
B-02-01 26ACA	871	868	-3.2
B-02-01 25BBB	844	866	21.6
B-02-01 26AAA	853	865	12.1
A-02-01 20DDD2	923	901	-21.8
A-02-01 20CCC2	908	891	-17.4
B-02-01 23DCC	840	865	25.5
A-02-01 20DCC	912	895	-17.2
B-02-01 23DCB	841	864	22.7
A-02-01 20CAC	908	892	-16.1
A-02-01 20DAA	927	902	-25.1
B-02-01 23DBB	838	863	24.7
A-02-01 20BCC2	911	889	-21.6

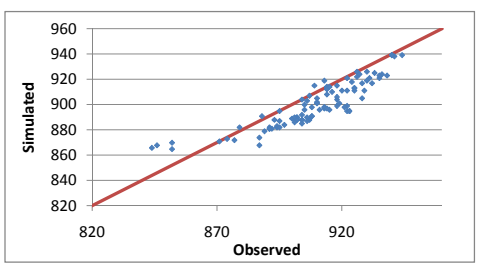
ME	*-11.88*
AME	*15.35*
RMSE	*16.61*



1991/1992 Calibration Data (Avondale Study Area)

Local ID	Measured Elevations (ft-amsl)	Simulated Elevations (ft-amsl)	Unweighted Residual (feet)
B-01-01 34AAA	914	908	-5.7
A-01-01 29DCD	941	938	-2.7
A-01-01 28CAC	944	939	-5.2
A-01-01 29DAA2	940	939	-1.3
A-01-01 29DAA1	940	939	-1.3
B-01-01 27DAB1	910	902	-7.6
B-01-01 27DAB2	906	903	-3.5
B-01-01 25ADA	928	917	-11.1
A-01-01 30AAC2	926	926	0.4
A-01-01 30AAC1	933	925	-8.1
A-01-01 30BAA2	931	921	-9.6
B-01-01 25BAA	925	913	-11.6
A-01-01 30BAA1	922	921	-0.8
A-01-01 19CCD	930	919	-11.2
A-01-01 19DCD1	936	924	-11.7
B-01-01 28ABA	902	890	-12.1
A-01-01 19CCC	932	917	-14.9
B-01-01 28AAB	902	890	-11.5
B-01-01 22ACD	913	897	-16.1
A-01-01 19ACB2	913	919	6.4
A-01-01 19ABB	935	921	-14.1
B-01-01 15CCB	906	890	-15.6
B-01-01 13DBC	929	911	-18.3
B-01-01 16DBD	901	888	-12.9
A-01-01 18ACB	924	918	-6.0
B-01-01 16ADB	904	888	-16.0
B-01-01 15BAD	904	892	-11.9
B-01-01 16AAC	902	888	-14.2
A-01-01 17BBB	935	923	-11.8
B-01-01 16AAB	907	888	-19.2
B-01-01 10CCD	900	889	-10.6
A-01-01 07CCD	925	913	-11.6
B-01-01 11CCB2	922	895	-26.9
B-01-01 11CCB1	923	895	-28.2
B-01-01 09DDB	906	887	-19.1
B-01-01 10CBD	893	888	-4.6
A-01-01 08CAB	938	923	-15.3
B-01-01 10CBB	904	888	-16.4
B-01-01 10ACD	908	891	-16.6
A-01-01 09BAC	930	926	-3.7
B-01-01 10BDA	902	889	-13.1
A-01-01 08BAA	926	922	-4.1
B-01-01 11AAA	922	899	-23.2
A-01-01 09BBB2	927	924	-2.7
B-01-01 12BAA2	918	904	-14.1
B-01-01 11AAB	921	898	-23.1
A-01-01 06CDD	925	911	-13.9
B-01-01 11BAB	923	895	-28.1
B-01-01 09AAB	904	885	-18.8
B-01-01 10AAA2	908	891	-16.8
B-01-01 03DAC	901	890	-11.4
A-01-01 06CBB2	918	906	-12.1
B-01-01 01CAB	918	899	-18.7
A-01-01 06CBB1	928	905	-22.8
B-01-01 01CAA	919	901	-18.0
A-01-01 06DAA	918	915	-2.7
B-01-01 02DAA	915	896	-19.2
B-01-01 04CAA	894	882	-11.8
B-01-01 01BDA	913	898	-15.0
B-01-01 02BCB	902	888	-14.2
B-01-01 01BAC	913	898	-14.8
B-01-01 01BAD	914	897	-16.6
B-01-01 04ABA2	892	881	-11.5
B-01-01 04AAB	891	881	-9.8
B-01-01 03BAA	897	884	-13.4
B-01-01 02BBB	901	886	-15.2
B-02-01 36CDD	911	896	-14.7
A-02-01 32DDA	909	915	5.9
B-02-01 34DDA	894	883	-11.3
A-02-01 31DAA	916	910	-6.3
A-02-01 32DAB2	914	913	-0.9
B-02-01 34CAA2	889	879	-10.0
B-02-01 36ACD	905	896	-8.9
A-02-01 32ACA	914	914	-0.5
A-02-01 32AAC	914	912	-1.7
B-02-01 35ABD	895	882	-13.0
B-02-01 36BAA	895	887	-7.5
B-02-01 36BBA3	891	882	-8.7
B-02-01 35AAB	891	881	-10.4
A-02-01 30DDD2	904	904	-0.1
A-02-01 29DDD2	915	914	-1.1
B-02-01 27DCC	887	874	-12.9
B-02-01 27CBC	887	868	-18.8
B-02-01 26CBC2	877	872	-5.3
A-02-01 30CBB	888	891	2.7
A-02-01 30CAA2	895	895	0.2
A-02-01 29CAA2	907	907	-0.1
B-02-01 25BCB	874	873	-1.1
B-02-01 26ACA	871	871	0.0
B-02-01 25ACA	879	882	3.3
B-02-01 25BBB	852	870	18.3
A-02-01 20DDD2	920	911	-8.5
A-02-01 20CCC2	905	900	-5.4
A-02-01 20DCC	910	905	-5.5
B-02-01 23DDD	846	868	22.2
B-02-01 23DCB	844	866	22.0
A-02-01 20CAC	910	901	-9.0
A-02-01 20DAA	922	911	-10.7
B-02-01 23DBB	852	865	12.7
A-02-01 20BCC2	908	898	-9.9

ME	*-9.12*
AME	*11.01*
RMSE	*12.95*



APPENDIX TABLE C-3

REFINED MODEL UNWEIGHTED CALIBRATION RESIDUALS - ENTIRE MODEL DOMAIN

2002/2003 Calibration Data (Entire Model Domain)

Local ID	Measured Elevations (ft-amsl)	Simulated Elevations (ft-amsl)	Unweighted Residual (feet)
C-01-05 03BAA1	838.0	855.0	17.0
C-01-05 03BAA2	838.0	855.0	17.0
C-01-05 03BAA3	836.0	854.6	18.6
B-01-05 35ABA	858.0	888.8	30.8
B-01-05 36CCB	827.0	867.7	40.7
C-01-05 01DCC	833.0	851.1	18.1
C-01-05 13AAB	813.0	835.1	22.1
B-01-05 24ABA	927.0	919.1	-7.9
B-01-05 36AAA	854.0	877.6	23.6
B-01-04 19BBB2	930.0	915.3	-14.7
C-01-04 06BBA	843.0	858.8	15.8
B-01-04 31BCD	850.0	866.5	16.5
C-01-04 07BDD	823.0	841.2	18.2
C-01-04 18BAA	815.0	829.1	14.1
B-01-04 19BAA	928.0	909.7	-18.3
C-01-04 06DBC	838.0	847.2	9.1
B-01-04 19AAA	934.0	906.5	-27.5
C-01-04 18AAA	820.0	823.8	3.8
C-01-04 19AAA1	800.0	800.3	0.3
C-01-04 18DAA	811.0	812.3	1.3
B-01-04 19DAD2	956.0	893.3	-62.7
C-01-04 08BCB	831.0	839.3	8.3
B-01-04 32BBB2	844.0	866.0	22.0
C-01-04 08BBA	832.0	842.6	10.6
C-01-04 05BAB	834.0	853.3	19.3
C-01-04 17DCB	808.0	802.5	-5.5
B-01-04 29ACC	888.0	875.6	-12.4
C-01-04 05CAA	834.0	847.6	13.6
B-01-04 32ABA	858.0	866.5	8.5
B-01-04 32DAA	852.0	857.3	5.3
B-01-04 20DDA2	929.0	885.1	-43.9
C-01-04 09BCB2	832.0	833.7	1.7
B-01-04 29AAD	864.0	876.0	12.0
C-01-04 04CDD	827.0	832.7	5.7
B-01-04 33BDA	853.0	859.5	6.5
B-01-04 16DBA	876.0	902.0	26.0
B-01-04 16DCD	877.0	893.6	16.6
C-01-04 27BBC1	792.0	789.0	-3.0
C-01-04 15CBB	775.0	800.3	25.3
B-01-04 28DAA	864.0	866.8	2.8
C-01-04 04ADA	844.0	842.1	-1.9
B-01-04 34BCD	848.0	851.8	3.8
C-01-04 27BDC	792.0	789.5	-2.5
B-01-04 34BBA	854.0	855.8	1.8
B-01-04 27DBC	858.0	860.5	2.5
C-01-04 03BDA	840.0	835.6	-4.4
B-01-04 27ABB	869.0	870.0	1.0
C-01-04 03ABB	843.0	842.6	-0.4
C-01-04 03DCB	835.0	825.7	-9.3
B-01-04 35BBC	852.0	851.6	-0.4
B-01-04 27AAD	856.0	865.3	9.3
C-01-04 02CBC	835.0	820.4	-14.6
C-01-04 02DBB2	834.0	819.8	-14.2
B-01-04 35AAD	847.0	847.7	0.7
B-01-04 36BBB	854.0	850.0	-4.0
C-01-04 01BDD1	837.0	824.7	-12.3
B-01-04 25DBC	852.0	852.6	0.6
B-01-04 25AAC	849.0	858.7	9.7
C-01-03 06BCB	841.0	829.8	-11.2
B-01-03 31BCB	852.0	848.3	-3.7
B-01-03 19CBB	868.0	862.5	-5.5
B-05-03 30BAA	1295.0	1263.9	-31.1
C-01-03 06BDB	842.0	833.9	-8.1
B-04-03 19DBA	1225.0	1224.5	-0.5
B-01-03 30BAA	852.0	859.5	7.5
B-06-03 29CBC	1331.0	1298.5	-32.5
B-01-03 31DDA	821.0	845.4	24.4
C-01-03 05BAA2	804.0	841.1	37.1
B-01-03 32BAA	850.0	850.6	0.6
B-01-03 29BAA	857.0	859.0	2.0
B-01-03 20CAA	855.0	862.6	7.6
B-04-03 05AAC	1245.0	1224.2	-20.8
C-01-03 05AAB	840.0	840.1	0.1
B-06-03 33CCC	1270.0	1273.0	3.0
B-01-03 28CBB	853.0	854.2	1.2
B-01-03 17ADA	845.0	866.6	21.6
B-01-03 16CCC	862.0	863.8	1.8
B-06-03 33DCB	1253.0	1267.1	14.1
C-01-03 04CDD	839.0	821.5	-17.5
B-01-03 21DBB	849.0	860.1	11.1
B-01-03 34BBB1	850.0	847.6	-2.4
B-01-03 34CCB	845.0	837.5	-7.5
B-01-03 27CBB	852.0	851.2	-0.8
B-01-03 34CAD	845.0	836.6	-8.4
B-05-03 22ADD	1225.0	1216.7	-8.3
B-05-03 15AAA	1228.0	1226.8	-1.2
B-01-03 34ADD2	846.0	837.7	-8.3
B-01-03 22AAD	858.0	854.9	-3.1
B-01-03 23CBB	844.0	854.3	10.3
B-05-03 23ABB	1218.0	1210.5	-7.5
B-01-03 35BDD2	850.0	837.2	-12.8
B-01-03 23ACB	827.0	854.2	27.2
B-01-03 14DBB	839.0	855.5	16.5
B-01-03 14AAB	838.0	855.8	17.8
B-05-03 13BCA2	1202.0	1204.6	2.6
C-01-03 02DAD	846.0	836.4	-9.6
B-01-03 25BBC1	852.0	850.0	-2.0
B-01-03 25BBB	851.0	851.4	0.4
B-01-03 13CBC	845.0	855.2	10.2
B-01-03 36BBD	849.0	842.2	-6.8
C-01-03 01BDD2	847.0	835.1	-11.9
B-06-03 36DDD	1207.0	1224.1	17.1
B-06-03 36DDD	1206.0	1224.1	18.1
B-01-03 36AAB	852.0	846.5	-5.5
C-01-03 01ADD	848.0	835.3	-12.7
B-01-02 30ABB	854.0	851.7	-2.3
B-01-02 31DCC1	847.0	839.9	-7.1
B-01-02 18ACC	850.0	857.8	7.8
B-06-02 31BDD	1206.0	1222.1	16.1
B-01-02 18ACD	819.0	857.5	38.5
C-01-02 06CAD	850.0	836.6	-13.4
B-01-02 20BBB	859.0	857.2	-1.8
B-01-02 29CCC	851.0	846.2	-4.8
B-01-02 17BBC	859.0	858.9	-0.1

1997/1998 Calibration Data (Entire Model Domain)

Local ID	Measured Elevations (ft-amsl)	Simulated Elevations (ft-amsl)	Unweighted Residual (feet)
D-01-02 29BDD	991.0	985.4	-5.6
C-01-04 27BDC	791.0	788.4	-2.6
D-01-02 20CDD	990.0	982.6	-7.4
C-01-04 27BBC1	792.0	787.6	-4.4
D-01-02 20DCB	991.0	980.4	-10.6
D-01-02 19DAA	989.0	976.6	-12.4
D-01-02 20BDA	993.0	977.5	-15.5
C-01-02 19ACC	847.0	843.1	-3.9
C-01-02 19ACD1	850.0	843.6	-6.4
D-01-02 19AAA	986.0	974.4	-11.6
D-01-02 18DCD	982.0	973.3	-8.7
D-01-01 13DDD1	970.0	972.5	2.5
D-01-01 13DDD1	970.0	971.7	1.7
D-01-01 13DDD1	970.0	971.6	1.6
C-01-04 24ADA	806.0	800.5	-5.5
C-01-04 19AAA1	786.0	797.9	11.9
C-01-03 14DAD	841.0	840.9	-0.1
D-01-02 18ADD	988.0	973.5	-14.5
C-01-04 17DCB	812.0	798.5	-13.5
C-01-04 15CBB	797.0	795.3	-1.7
C-01-02 18ACA	845.0	846.4	1.4
D-01-02 07DCC	978.0	971.1	-6.9
C-01-03 13BBC	834.0	839.9	5.9
C-01-05 13AAD	817.0	828.4	11.4
C-01-04 15ABB1	812.0	788.1	-23.9
C-01-04 15ABB2	802.0	785.7	-16.3
C-01-04 18AAA	823.0	820.9	-2.1
D-01-02 07CBA	972.0	969.6	-2.4
C-01-05 13AAB	818.0	834.5	16.5
C-01-04 10CCC	815.0	787.8	-27.2
C-01-04 08DDD	825.0	815.6	-9.4
C-01-03 08CBD	820.0	818.7	-1.3
C-01-04 11DCB	815.0	796.1	-18.9
C-01-04 11CBC	812.0	792.1	-19.9
D-01-02 03CDD	1019.0	984.4	-34.6
C-01-04 08BCB	834.0	834.9	0.9
C-01-04 09BCB2	834.0	831.3	-2.7
C-01-03 04CDD	840.0	830.3	-9.7
C-01-04 02CCC	831.0	812.3	-18.7
D-01-03 04ACC	1031.0	1054.2	23.2
C-01-02 06CAD	851.0	851.0	0.0
C-01-04 01DDA	837.0	824.4	-12.6
C-01-03 02DAD	849.0	845.8	-3.2
D-01-03 06BAD	1033.0	1020.6	-12.4
C-01-03 03DAA	842.0	837.3	-4.7
C-01-03 01BDD2	844.0	849.2	5.2
C-01-04 06DBC	842.0	845.5	3.5
C-01-03 01ADD	853.0	851.3	-1.7
C-01-02 06ADD	847.0	854.7	7.7
C-01-02 06ADD	854.0	854.7	0.7
C-01-04 05CAA	834.0	843.5	9.5
C-01-02 04BBD	861.0	861.1	0.1
C-01-02 05BAD	857.0	856.3	-0.7
A-01-01 35DDC	951.0	963.1	12.1
A-01-02 35DDD	1002.0	1001.2	-0.8
C-01-04 04ADA	844.0	836.9	-7.1
A-01-02 32DDD	990.0	969.3	-20.7
C-01-04 03BDA	840.0	831.0	-9.0
A-01-02 32CCD	966.0	962.6	-3.4
A-01-01 36DDA	965.0	962.5	-2.5
C-01-03 05AAB	841.0	845.8	4.8
A-01-02 33CBD	978.0	968.8	-9.2
C-01-04 03ABB	843.0	837.6	-5.4
C-01-04 05BAB	837.0	850.4	13.4
C-01-04 06BBA	844.0	856.9	12.9
C-01-05 03BAA1	840.0	854.5	14.5
C-01-05 03BAA2	840.0	854.0	14.0
C-01-05 03BAA3	839.0	854.2	15.2
A-01-03 36BCC	1059.0	1093.9	34.9
B-01-02 32DCB	857.0	861.1	4.1
A-01-03 35ADD	1060.0	1092.7	32.7
B-01-03 34CAD	850.0	850.3	0.3
B-01-05 36CCB	840.0	864.2	24.2
A-01-03 35BAA	1047.0	1083.1	36.1
B-01-04 36CBB	844.0	842.8	-1.2
A-01-01 36AAD	957.0	960.8	3.8
B-01-04 34BCD	846.0	846.8	0.8
A-01-01 33AAD	939.0	955.0	16.0
B-01-03 35BDD2	851.0	854.7	3.7
B-01-04 32DAA	854.0	855.7	1.7
B-01-04 31BCD	852.0	863.3	11.3
B-01-05 35DAA2	855.0	868.7	13.7
A-01-02 32AAA2	977.0	962.7	-14.3
A-01-02 32BAA	974.0	961.6	-12.4
A-01-02 31AAA	964.0	959.8	-4.2
B-01-02 36BBC	876.0	876.6	0.6
A-01-02 26DDD	999.0	987.6	-11.4
A-01-01S25BAB	959.0	962.3	3.3
B-01-03 31BCB	850.0	847.1	-2.9
A-01-01S25BBA	954.0	957.6	3.6
B-01-03 36BBD	854.0	859.9	5.9
B-01-04 35ACB2	836.0	844.3	8.3
B-01-04 35AAD	823.0	844.8	21.8
B-01-04 35BBC	849.0	846.9	-2.1
B-01-04 33BDA	855.0	856.1	1.1
B-01-02 34ABB	865.0	868.2	3.2
B-01-02 26CCC	867.0	871.0	4.0
B-01-01 28CDC	895.0	894.7	-0.3
A-01-02N29DDA	975.0	964.6	-10.4
B-01-03 36AAB	858.0	863.7	5.7
B-01-03 34BBB1	853.0	857.5	4.5
B-01-03 32BAA	850.0	854.3	4.3
B-01-01 29DDA2	892.0	887.0	-5.0
B-01-02 29CCC	857.0	865.9	8.9
B-01-04 36BBB	853.0	847.3	-5.7
B-01-04 34BBA	852.0	851.7	-0.3
B-01-04 32BBB2	856.0	866.5	10.5
B-01-04 32ABA	862.0	865.7	3.7
A-01-03 27CAA	1030.0	1054.4	24.4
B-01-05 36AAA	858.0	875.6	17.6
A-01-04 30BDD	1086.0	1102.5	16.5
B-01-01 29CAD	891.0	882.4	-8.6
A-01-01S26CAA	952.0	958.6	6.6
B-01-02 27DAD	870.0	869.6	-0.4

1991/1992 Calibration Data (Entire Model Domain)

Local ID	Measured Elevations (ft-amsl)	Simulated Elevations (ft-amsl)	Unweighted Residual (feet)
C-01-04 27DAA	818.0	793.7	-24.3
C-01-04 27BDC	794.0	792.3	-1.7
D-01-02 20CDD	986.0	977.8	-8.2
C-01-04 27BBC1	793.0	790.7	-2.3
C-01-05 24CCB	788.0	795.8	7.8
C-01-02 19ACD1	857.0	843.7	-13.3
C-01-02 19ACD3	854.0	843.7	-10.3
D-01-02 19AAA	982.0	972.2	-9.8
D-01-02 18DCD	978.0	971.7	-6.3
D-01-01 13DDD2	975.0	969.9	-5.1
D-01-01 13DDD1	956.0	969.9	13.9
D-01-01 13DDD1	958.0	969.8	11.8
D-01-01 13DDD1	958.0	970.0	12.0
C-01-05 13CDD	804.0	812.2	8.2
C-01-03 13CBD	841.0	840.5	-0.5
C-01-03 14DAD	844.0	839.8	-4.2
D-01-02 18ADD	984.0	974.0	-10.0
C-01-04 15CBB	791.0	792.5	1.5
C-01-04 17DAA	788.0	795.8	7.8
C-01-02 18ACA	851.0	845.0	-6.0
C-01-03 13ABC	851.0	840.8	-10.2
D-01-02 07DCC	975.0	973.1	-1.9
C-01-04 15ACB1	809.0	785.2	-23.8
C-01-03 13BBC	837.0	838.2	1.2
C-01-05 13AAD	817.0	826.2	9.2
C-01-04 15ABB1	812.0	780.2	-31.8
C-01-04 15ABB2	801.0	776.9	-24.1
C-01-04 18AAA	820.0	816.7	-3.3
C-01-02 08CDA	841.0	846.7	5.7
D-01-02 07CBA	954.0	971.5	17.5
C-01-05 13AAB	815.0	832.4	17.4
C-01-04 10CCC	805.0	776.2	-28.8
C-01-04 08DDD	819.0	808.9	-10.1
C-01-04 10BCC	801.0	800.2	-0.8
C-01-04 07BDD	826.0	833.2	7.2
D-01-02 10BBB	1015.0	1000.0	-15.0
D-01-02 03CDD	1019.0	1005.5	-13.5
D-01-02 06DDD	975.0	976.7	1.7
C-01-04 08BCB	831.0	827.3	-3.7
C-01-04 09BCB2	829.0	822.1	-6.9
C-01-03 04CDD	839.0	821.8	-17.2
D-01-02 01DBA	1030.0	1033.1	3.1
D-01-02 03CBA	994.0	1002.6	8.6
D-01-02 04ADD	1002.0	997.4	-4.6
C-01-05 01DCC	835.0	842.0	7.0
D-01-02 05ADD	982.0	982.8	0.8
C-01-04 04DDA	829.0	819.9	-9.1
C-01-04 03DCB	828.0	811.5	-16.5
C-01-04 01DDA	835.0	819.6	-15.4
C-01-03 02DAD	847.0	839.3	-7.7
C-01-04 02CBC	829.0	807.0	-22.0
D-01-03 06BAD	1032.0	1032.9	0.9
C-01-04 02DBB2	827.0	810.7	-16.3
C-01-03 01BDD2	850.0	843.1	-6.9
C-01-03 01ADD	846.0	846.3	0.3
D-01-03 06AAA	1018.0	1034.6	16.6
D-01-04 05BBB	832.0	832.0	0.0
C-01-04 05CAA	832.0	820.9	-11.1
C-01-04 01BDD1	830.0	821.4	-8.6
C-01-04 01BCC	836.0	825.0	-11.0
C-01-03 06BCB	1073.0	1087.7	14.7
A-01-03 35DDD	953.0	961.7	8.7
A-01-01 35DDC	1034.0	1018.7	-15.3
A-01-02 35DDD	838.0	829.0	-9.0
C-01-03 06BDB	981.0	978.0	-3.0
A-01-02 32DDD	1023.0	1029.3	6.3
A-01-03 31DDA	970.0	965.0	-5.0
A-01-01 36DDA	838.0	837.3	-0.7
C-01-03 05AAB	854.0	854.1	0.1
B-01-02 32CCD	979.0	976.8	-2.2
A-01-02 33CBD	853.0	850.7	-2.3
B-01-02 31DCC2	851.0	850.9	-0.1
B-01-02 31DCC1	838.0	825.7	-12.3
C-01-04 03ABB	832.0	836.1	4.1
C-01-04 05BAB	849.0	848.0	-1.0
C-01-05 01AAB	838.0	844.2	6.2
C-01-04 06BBA	838.0	853.2	15.2
C-01-05 03BAA1	836.0	852.8	16.8
C-01-05 03BAA3	856.0	856.5	0.5
B-01-02 32DCB	844.0	844.0	0.0
B-01-03 34CCB	1057.0	1087.8	30.8
A-01-03 35ADD	1082.0	1096.1	14.1
A-01-03 36ADA	855.0	853.1	-1.9
B-01-02 31DBC	1022.0	1050.9	28.9
A-01-03 33ADB	1032.0	1050.8	18.8
B-01-03 34ADD2	848.0	845.6	-2.4
B-01-03 31DBA	847.0	839.2	-7.8
A-01-02 35BAB1	994.0	993.6	-0.4
A-01-02 35BAB2	994.0	993.6	-0.4
B-01-02 32ADD	861.0	861.1	0.1
A-01-01 36AAD	962.0	963.2	1.2
B-01-04 34BCD	841.0	833.3	-7.7
B-01-03 35BDD2	851.0	847.4	-3.6
B-01-04 32DAA	846.0	840.2	-5.8
B-01-04 31BCD	846.0	848.8	2.8
B-01-05 35DAA2	849.0	862.2	13.2
A-01-03 25DDC	1078.0	1094.3	16.3
A-01-02 32AAA2	978.0	967.6	-10.4
A-01-02 32BAA	977.0	965.8	-11.2
A-01-02 31AAA	964.0	963.6	-0.4
B-01-02 36BBC	873.0	874.8	1.8
A-01-02 26DDD	998.0	1000.7	2.7
B-01-03 35ACB	846.0	849.0	3.0
A-01-01S25BAB	966.0	962.5	-3.5
B-01-03 31BCB	846.0	836.1	-9.9
A-01-01S25BBA	960.0	959.3	-0.7
B-01-01 34AAA	914.0	914.3	0.3
B-01-03 36BBD	850.0	852.1	2.1
A-01-01 29DCD	941.0	945.1	4.1
B-01-04 35ACB2	808.0	832.3	24.3
B-01-04 35AAD	826.0	832.5	6.5
B-01-04 35BBC	845.0	833.7	-11.3
B-01-04 33BDA	847.0	840.0	-7.0
B-01-02 35BAA2	867.0	872.4	5.4

APPENDIX TABLE C-3

REFINED MODEL UNWEIGHTED CALIBRATION RESIDUALS - ENTIRE MODEL DOMAIN

B-01-02 05CBB	850.0	863.1	13.1
B-01-02 08BCC	850.0	860.8	10.8
B-01-02 17CBB	853.0	858.0	5.0
B-01-02 17CCC	853.0	857.2	4.2
C-01-02 19ACC	843.0	839.7	-3.3
C-01-02 19ACD1	846.0	840.0	-6.0
C-01-02 18ACA	843.0	839.6	-3.4
B-05-02 08CCB	1182.0	1192.0	10.0
B-01-02 29CBA	831.0	848.6	17.6
B-01-02 17CAA	852.0	858.7	6.7
C-01-02 06ADD	848.0	836.6	-11.4
B-01-02 32DCB	850.0	843.9	-6.1
B-01-02 08ABB2	854.0	862.9	8.9
B-01-02 29DCA	858.0	847.1	-10.9
B-05-02 17ABD	1154.0	1179.4	25.4
B-02-02 05AAB	827.0	818.5	-8.5
B-01-02 05AAA	849.0	864.5	15.5
C-01-02 08CDA	835.0	841.0	6.0
B-02-02 20DDD2	818.0	854.4	36.4
C-01-02 05BAD	851.0	838.8	-12.2
B-02-02 17DDD	830.0	840.2	10.2
B-01-02 16BBB	850.0	860.6	10.6
B-01-02 09CBC	869.0	861.5	-7.5
B-01-02 09BBB2	848.0	863.1	15.1
B-01-02 28CBD	857.0	851.5	-5.5
B-01-02 21CBA	862.0	856.9	-5.1
B-01-02 28DBB	860.0	852.4	-7.6
B-01-02 09BAA	840.0	863.3	23.3
B-01-02 09ABB	884.0	863.3	-20.7
B-02-02 21BDD	833.0	850.4	17.4
B-01-02 04DBB2	846.0	865.3	19.3
B-01-02 09ACC	857.0	863.1	6.1
B-02-02 16ABB	805.0	831.3	26.3
B-02-02 04DCB	838.0	822.0	-16.0
B-01-02 21DCA4	860.0	856.1	-3.9
C-01-02 04BBD	855.0	848.1	-6.9
C-01-02 04BAC	853.0	848.3	-4.7
B-03-02 21ABA	925.0	834.5	-90.5
B-01-02 15CCC	865.0	860.8	-4.2
B-01-02 09ADA2	849.0	863.2	14.2
B-01-02 27CBB1	862.0	853.5	-8.5
B-02-02 22BBB	815.0	840.7	25.7
B-02-02 03BBB	836.0	818.8	-17.2
B-02-02 03BBB	833.0	818.8	-14.2
B-01-02 03CBB3	846.0	865.7	19.7
B-05-02 15CCB	1115.0	1151.2	36.2
B-04-02 16AAD	1082.0	989.2	-92.8
B-03-02 03CBA	889.0	855.9	-33.1
B-01-02 27CAA	861.0	851.6	-9.4
B-04-02 34BBA	958.0	881.5	-76.5
B-01-02 34ABB	857.0	850.4	-6.6
B-01-02 22DBC	866.0	857.9	-8.1
B-01-02 03DBB	847.0	866.8	19.8
B-02-02 22ABB	820.0	836.3	16.3
B-02-02 34BAA	842.0	860.1	18.1
B-03-02 03BAA	885.0	859.2	-25.8
B-02-02 10DCC	797.0	824.7	27.7
B-03-02 34BAA	819.0	815.9	-3.1
B-01-02 03DCC	861.0	865.9	4.9
B-03-02 27ABB	824.0	819.6	-4.4
B-01-02 03DCD	859.0	866.2	7.2
B-01-02 22DDC	864.0	855.9	-8.1
B-01-02 22DBA1	865.0	859.3	-5.7
B-04-02 27DCD	875.0	872.2	-2.8
B-04-02 34DBA	871.0	860.4	-10.6
B-01-02 27DAD	861.0	845.2	-15.8
B-02-02 22AAA	815.0	831.3	16.3
B-02-02 15AAA	789.0	816.6	27.6
B-01-02 11BCC	843.0	867.0	24.0
B-01-02 02CCC4	865.0	867.6	2.6
B-01-02 02BBB2	840.0	870.3	30.3
B-02-02 35BBB	847.0	861.0	14.0
B-02-02 14BCC	802.0	823.6	21.6
B-03-02 35BBB	806.0	810.4	4.4
B-01-02 26CCC	858.0	849.0	-9.0
B-03-02 22AAA	836.0	824.8	-11.2
B-03-02 15AAA	843.0	830.2	-12.8
B-03-02 14BCB2	854.0	826.0	-28.0
B-03-02 27AAA	815.0	816.9	1.9
B-02-02 11BBB	786.0	807.9	21.9
B-01-02 02CCD	872.0	869.0	-3.0
B-03-02 02CBC	827.0	845.1	18.1
B-04-02 35CCC	859.0	850.0	-9.0
B-04-02 35CBB	824.0	853.9	29.9
B-01-02 26BDC	863.0	848.4	-14.6
B-01-02 14CDA	871.0	865.7	-5.3
B-01-02 14CAA	869.0	866.8	-2.2
B-05-02 26BBA	1122.0	1107.4	-14.6
B-01-02 02BAA	857.0	871.2	14.2
B-01-02 23CAD1	869.0	861.2	-7.8
B-01-02 14BAA1	878.0	868.1	-9.9
B-01-02 23CAD2	867.0	860.7	-6.3
B-03-02 26CDD	799.0	807.7	8.7
B-04-02 11BDB	1066.0	966.6	-99.4
B-01-02 11ABB	877.0	869.3	-7.7
B-02-02 14ABB	779.0	807.2	28.2
B-04-02 35BDD	782.0	848.6	66.6
B-03-02 26BAA	813.0	814.0	1.0
B-05-02 35BAA	1092.0	1065.0	-27.0
B-03-02 14BAA	825.0	828.4	3.4
B-03-02 11BAA	815.0	838.4	23.4
B-03-02 23BAA	796.0	821.5	25.5
B-03-02 02BAA	843.0	844.7	1.7
B-01-02 02DBA	848.0	870.2	22.2
B-04-02 26DBB	856.0	860.6	4.6
B-05-02 23DCA	1078.0	1108.8	30.8
B-01-02 14DDB	874.0	866.5	-7.5
B-01-02 23AAB1	875.0	866.0	-9.0
B-04-02 26ABA	849.0	868.8	19.8
B-01-02 36BBC	867.0	859.5	-7.5
B-02-02 24CBB3	803.0	828.9	25.9
B-01-02 01CCC	860.0	870.8	10.8
B-01-02 01BBB2	868.0	870.9	2.9
B-02-02 36BBB3	845.0	864.0	19.0
B-02-02 25CBB2	832.0	854.1	22.1
B-02-02 24CCC	814.0	840.1	26.1
B-02-02 02ADD1	776.0	795.1	19.1
B-02-02 01BBB	783.0	794.0	11.0
B-02-02 12BBB	775.0	791.8	16.8
B-03-02 23AAA	819.0	818.4	-0.6

B-01-01 29CBB	891.0	880.7	-10.3
B-01-01 30CBA	880.0	876.7	-3.3
B-01-02 28CBD	865.0	869.4	4.4
B-01-04 25DBC	847.0	851.8	4.8
B-01-02 25DBA2	882.0	878.2	-3.8
B-01-01 27DAB2	910.0	911.6	1.6
B-01-01 30DBB	885.0	879.4	-5.6
B-01-01 29ADD	899.0	884.6	-14.4
B-01-04 27DBC	858.0	856.0	-2.0
B-01-02 29CBA	847.0	866.7	19.7
B-01-02 27CAA	869.0	871.2	2.2
B-01-02 26BDC	871.0	873.6	2.6
B-01-03 27CBB	853.0	860.6	7.6
B-01-01 25ADA	926.0	923.4	-2.6
B-01-03 28CBB	852.0	859.4	7.4
A-01-01 28BCB	935.0	941.0	6.0
A-01-04 30BAB	1083.0	1101.1	18.1
A-01-01 30AAC2	932.0	930.5	-1.5
A-01-01 30AAC1	928.0	929.6	1.6
B-01-04 28DAA	865.0	863.6	-1.4
B-01-04 28DAA	864.0	863.6	-0.4
B-01-01 28BCA2	897.0	887.9	-9.1
B-01-02 26BCB	871.0	874.4	3.4
B-01-04 29ACC	890.0	875.5	-14.5
A-01-02 24DDC2	999.0	981.6	-17.4
A-01-02 29BBB	960.0	962.4	2.4
B-01-01 25BAA	923.0	917.9	-5.1
A-01-01 30BAA1	928.0	925.3	-2.7
A-01-01 26AAA	949.0	953.6	4.6
A-01-01 19DCD1	932.0	927.5	-4.5
B-01-01 28ABA	900.0	895.1	-4.9
B-01-01 28AAB	902.0	895.8	-6.2
A-01-01 21DDA3	940.0	942.3	2.3
B-01-04 27AAD	856.0	862.5	6.5
B-01-04 27ABB	866.0	866.2	0.2
B-01-02 22DCC	872.0	875.2	3.2
B-01-03 30AAA	857.0	860.9	3.9
B-01-01 19CCC	880.0	880.4	0.4
A-01-01 21DDA2	939.0	942.8	3.8
B-01-03 30BAA	849.0	863.2	14.2
B-01-03 29BAA	856.0	862.3	6.3
A-01-02 19DDA	952.0	955.7	3.7
B-01-04 26BAA	858.0	863.5	5.5
A-01-01 22CDA	936.0	945.0	9.0
B-01-04 29AAA	944.0	884.4	-59.6
A-01-01 23DDA	951.0	949.8	-1.2
B-01-01 20DAC	894.0	885.5	-8.5
A-01-02 19CAD	956.0	955.9	-0.1
A-01-02N22DAB	993.0	966.6	-26.4
B-01-04 21CDD	892.0	881.9	-10.1
A-01-02 24DAB	994.0	975.9	-18.1
A-01-04 19ACC	1078.0	1101.6	23.6
B-01-02 21DCA3	869.0	872.6	3.6
B-01-02 23CAD2	875.0	878.4	3.4
B-01-01 21CBA	895.0	889.3	-5.7
B-01-04 20DDA2	943.0	888.1	-54.9
B-01-01 20DAA	893.0	886.9	-6.1
B-01-02 24DAA	882.0	880.2	-1.8
B-01-01 22ACD	910.0	901.9	-8.1
B-01-01 19CBA	883.0	880.3	-2.7
A-01-01 23DBA2	947.0	946.1	-0.9
B-01-02 22DBA1	867.0	877.1	10.1
B-01-02 20CBA	867.0	869.4	2.4
B-01-02 21CBA	868.0	872.0	4.0
B-01-03 20CAA	850.0	865.1	15.1
B-01-03 19CBB	862.0	873.9	11.9
B-01-04 20CBA	943.0	894.0	-49.0
B-01-03 23CBB	848.0	865.9	17.9
B-01-02 21BCC	866.0	871.8	5.8
B-01-03 21DBB	847.0	866.7	19.7
B-01-03 23ACB	842.0	865.9	23.9
A-01-01 24AAA	953.0	944.5	-8.5
A-01-01 21AAA	921.0	934.8	13.8
B-01-01 24ABB	922.0	912.6	-9.4
A-01-02 24BBB2	981.0	959.1	-21.9
A-01-03 18DDD	1002.0	989.1	-12.9
A-01-01 19ABB	931.0	920.3	-10.7
A-01-02 13CDD2	981.0	966.0	-15.0
B-01-01 19BBA	886.0	879.6	-6.4
B-01-02 23AAB2	870.0	879.6	9.6
A-01-02 19BAA	955.0	948.2	-6.8
A-01-02 18DDD2	950.0	946.5	-3.5
B-01-05 24ADB	929.0	913.5	-15.5
A-01-01 23AAB	943.0	940.3	-2.7
A-01-02 14CDD	974.0	955.9	-18.1
B-01-02 23AAB1	876.0	880.0	4.0
A-01-04 18DAD	1106.0	1106.8	0.8
B-01-02 13DCD	883.0	879.9	-3.1
B-01-02 21ABB	859.0	873.4	14.4
A-01-03 16CCB	1006.0	1006.8	0.8
B-01-02E19ABB2	862.0	868.7	6.7
B-01-02 20BBB	864.0	870.0	6.0
B-01-02 15CCC	873.0	875.3	2.3
B-01-04 19BBB2	923.0	914.0	-9.0
A-01-02 13DAD	989.0	970.8	-18.2
A-01-02 14CCB	969.0	952.6	-16.4
B-01-04 24AAA	846.0	860.6	14.6
B-01-03 16CCC	860.0	867.0	7.0
B-01-01 15DCA	908.0	898.5	-9.5
B-01-04 19BBB1	925.0	915.8	-9.2
A-01-01 14DDA	936.0	940.6	4.6
B-01-01 15CCB	904.0	894.3	-9.7
B-01-01 13DBC	926.0	910.2	-15.8
B-01-04 16DCD	877.0	894.1	17.1
B-01-04 19BAA	925.0	910.9	-14.1
B-01-02 14CDA	877.0	879.2	2.2
B-01-02 13DCA2	882.0	879.6	-2.4
B-01-02 14DDB	883.0	879.4	-3.6
B-01-02 25BBC1	875.0	879.0	4.0
B-01-02 17DBD	865.0	872.2	7.2
A-01-01 17DAA	938.0	927.1	-10.9
A-01-02 16DBB2	956.0	945.8	-10.2
A-01-02 15BCC2	958.0	946.2	-11.8
A-01-02 17ADD	956.0	944.1	-11.9
A-01-02 15ACC	960.0	947.4	-12.6
A-01-02 17CAA	952.0	943.0	-9.0
B-01-01 18BDC2	886.0	881.0	-5.0
B-01-02 14CAA	877.0	879.3	2.3
B-01-02 17CAA	863.0	871.4	8.4
B-01-02 17CBB	866.0	870.3	4.3

B-01-02 26CCC	866.0	870.5	4.5
A-01-02N29DDA	980.0	969.1	-10.9
B-01-02 30DCC	856.0	856.9	0.9
B-01-03 36AAB	855.0	856.6	1.6
B-01-03 34BBB1	847.0	850.8	3.8
B-01-03 32BAA	846.0	844.6	-1.4
B-01-04 36BBB	848.0	833.7	-14.3
A-01-01 28CAC	944.0	945.2	1.2
B-01-04 34BBA	847.0	836.4	-10.6
B-01-04 32BBB2	840.0	849.9	9.9
A-01-03 27CAA	1030.0	1049.3	19.3
B-01-02 29DCA	863.0	861.3	-1.7
B-01-05 36AAA	853.0	861.2	8.2
A-01-04 30BDD	1079.0	1098.8	19.8
B-01-05 35ABA	855.0	877.1	22.1
A-01-01 29DAA2	940.0	944.7	4.7
A-01-01S26CAA	959.0	958.9	-0.1
A-01-01 29DAA1	940.0	944.9	4.9
B-01-01 27DAB1	910.0	909.3	-0.7
B-01-02 28CBD	865.0	864.5	-0.5
B-01-04 25DBC	839.0	837.0	-2.0
B-01-02 25DBA2	881.0	878.0	-3.0
B-01-01 27DAB2	906.0	909.3	3.3
B-01-04 27DBC	851.0	840.1	-10.9
B-01-01 30ACC	858.0	881.6	23.6
B-01-02 27CAA	863.0	870.2	7.2
B-01-02 26BDC	871.0	873.3	2.3
B-01-02 30ACC	863.0	859.2	-3.8
B-01-03 27CBB	849.0	852.7	3.7
B-01-01 25ADA	928.0	923.8	-4.2
B-01-03 28CBB	849.0	849.8	0.8
A-01-01 30AAC2	926.0	932.9	6.9
A-01-01 30AAC1	933.0	931.8	-1.2
B-01-04 28DAA	857.0	846.1	-10.9
B-01-01 28BCA2	897.0	890.6	-6.4
B-01-02 26BCB	867.0	874.0	7.0
A-01-02 26AAA	992.0	985.4	-6.6
A-01-02 24DDC2	988.0	991.2	3.2
A-01-02 29BBB	967.0	964.6	-2.4
A-01-01 30BAA2	931.0	927.3	-3.7
B-01-03 25BBC2	853.0	857.2	4.2
B-01-01 25BAA	925.0	918.4	-6.6
A-01-01 30BAA1	922.0	927.4	5.4
A-01-01 19CCD	930.0	925.1	-4.9
A-01-01 19DCD1	936.0	930.4	-5.6
A-01-01N25BBB2	950.0	956.2	6.2
B-01-01 28ABA	902.0	895.9	-6.1
A-01-01 19CCC	932.0	923.2	-8.8
B-01-01 28AAB	902.0	896.5	-5.5
A-01-01 21DDA3	946.0	947.6	1.6
B-01-02 30ABB	859.0	859.5	0.5
B-01-04 27AAD	849.0	845.1	-3.9
B-01-04 27ABB	858.0	848.7	-9.3
B-01-02 22DCC	868.0	872.9	4.9
B-01-03 30AAA	852.0	848.1	-3.9
B-01-01 19CCC	877.0	880.1	3.1
B-01-03 30BAA	846.0	845.9	-0.1
B-01-03 29BAA	851.0	850.9	-0.1
A-01-02 19DDA	966.0	960.2	-5.8
B-01-04 26BAA	850.0	846.2	-3.8
A-01-01 22CDA	942.0	950.6	8.6
B-01-04 29AAA	936.0	863.7	-72.3
A-01-01 23DDA	957.0	955.9	-1.1
A-01-02 19CAD	963.0	960.1	-2.9
A-01-02N22DAB	985.0	971.0	-14.0
A-01-02 24DAB	988.0	985.6	-2.4
A-01-04 19ACC	1070.0	1099.1	29.1
B-01-02 21DCA3	863.0	867.2	4.2
A-01-03 23BCC	1034.0	1049.2	15.2
B-01-02 23CAD2	870.0	876.6	6.6
B-01-02 22DBB	870.0	873.0	3.0
B-01-02 20DAA2	863.0	864.6	1.6
B-01-01 21CBA	895.0	891.1	-3.9
B-01-02 20DAA1	863.0	864.9	1.9
B-01-04 20DDA2	934.0	869.6	-64.4
B-01-01 20DAA	893.0	888.6	-4.4
B-01-02 22DBA2	869.0	873.9	4.9
B-01-02 24ADD	883.0	879.9	-3.1
B-01-01 22ACD	913.0	902.9	-10.1
B-01-01 19CBA	886.0	880.1	-5.9
A-01-01 23DBA2	953.0	953.5	0.5
B-01-02 22DBA1	870.0	874.3	4.3
B-01-02 20CBA	861.0	862.7	1.7
B-01-02 21CBA	864.0	866.2	2.2
B-01-03 20CAA	848.0	853.7	5.7
B-01-03 24CBB2	851.0	857.9	6.9
B-01-04 20CBA	939.0	880.3	-58.7
B-01-03 23CBB	843.0	856.3	13.3
B-01-02 21BCC	865.0	865.9	0.9
A-01-03 20BAD2	1022.0	998.6	-23.4
B-01-03 21DBB	839.0	856.0	17.0
A-01-01 19ACB2	913.0	924.3	11.3
B-01-02 23BCB2	870.0	874.9	4.9
A-01-03 22BBB	1025.0	1026.9	1.9
B-01-03 23ACB	839.0	856.8	17.8
A-01-01 24AAA	960.0	952.2	-7.8
A-01-02 24BBB2	985.0	965.1	-19.9
A-01-01 19ABB	935.0	926.1	-8.9
A-01-02 13CDD2	985.0	974.7	-10.3
A-01-02 19BAA	966.0	954.9	-11.1
A-01-02 16CCC1	968.0	955.0	-13.0
B-01-02 24AAA2	871.0	878.4	7.4
A-01-03 13DDA	1050.0	1091.0	41.0
A-01-02 18DDD2	924.0	953.6	29.6
B-01-01 20BBB1	889.0	883.3	-5.7
A-01-01 23AAB	968.0	949.1	-18.9
A-01-02 14CDD	977.0	962.6	-14.4
B-01-02 23AAB1	872.0	877.1	5.1
B-01-02 23AAB1	877.0	877.1	0.1
A-01-04 18DAD	1080.0	1109.4	29.4
B-01-02 20ABA	863.0	865.3	2.3
B-01-02 13DCD	877.0	877.9	0.9
B-01-02 21ABB	855.0	867.4	12.4
A-01-03 16CCB	1006.0	1005.0	-1.0
B-01-02E19ABB2	858.0	861.4	3.4
B-01-02 15CCC	865.0	870.1	5.1
B-01-02E19ABB3	856.0	861.1	5.1
B-01-04 19BBB2	930.0	910.5	-19.5
A-01-02 13DAD	996.0	975.8	-20.2
A-01-02 14CCB	975.0	959.1	-15.9

APPENDIX TABLE C-3

REFINED MODEL UNWEIGHTED CALIBRATION RESIDUALS - ENTIRE MODEL DOMAIN

B-03-02 25BBB	837.0	809.3	-27.7
B-01-02 13BCA	882.0	868.4	-13.6
B-04-02 26DDD	833.0	846.0	13.0
B-03-02 01BBB	788.0	838.3	50.3
B-02-02 13BBA	782.0	793.5	11.5
B-04-02 24BCD	844.0	868.3	24.3
B-05-02 24BAB	1066.0	1121.8	55.8
B-01-02 01BAA	875.0	872.2	-2.8
B-05-02 13CDB	1063.0	1124.1	61.1
B-02-02 24DBB2	804.0	828.7	24.7
B-05-02 24CAD1	1067.0	1105.1	38.1
B-02-02 25CAA	833.0	854.1	21.1
B-02-02 36CAA	863.0	865.9	2.9
B-05-02 24CAD3	1062.0	1107.6	45.6
B-02-02 25ABB2	819.0	841.0	22.0
B-03-02 25BAA	780.0	804.1	24.1
B-03-02 36ABB	772.0	784.7	12.7
B-05-02 13CAA	1067.0	1127.6	60.6
B-02-02 13ABB	782.0	794.7	12.7
B-01-02 25DBA2	873.0	862.8	-10.2
B-03-02 12BAA	845.0	834.2	-10.8
B-05-02 24BAD	1062.0	1118.5	56.5
B-01-02 13DCD	873.0	868.1	-4.9
B-04-02 36BAA	818.0	839.0	21.0
B-04-02 25BAA	826.0	852.7	26.7
B-01-02 13DCA2	882.0	867.6	-14.4
B-02-02 01ABA	771.0	784.4	13.4
B-01-02 13ABA	908.0	870.5	-37.5
B-02-02 01AAA	751.0	783.8	32.8
B-01-02 12DAD	880.0	873.6	-6.4
B-01-01 19CCC	881.0	868.0	-13.0
B-01-02 12DAA2	885.0	874.1	-10.9
B-02-02 25DAA2	838.0	853.1	15.1
B-02-01 19BBB2	802.0	816.8	14.8
B-02-02 25AAA3	826.0	842.7	16.7
B-02-01 18CBB2	796.0	801.6	5.6
B-02-01 18BBB2	789.0	794.5	5.5
B-02-01 06CBB	774.0	786.1	12.1
B-03-01 31BCC	764.0	780.3	16.3
B-02-01 19CBB2	810.0	829.0	19.0
B-02-01 07CBB1	789.0	793.3	4.3
B-03-01 19CBB	810.0	812.0	2.0
B-03-02 12AAA	845.0	833.3	-11.7
B-01-01 30CBA	870.0	866.0	-4.0
B-03-01 06BCB	830.0	837.1	7.1
B-01-01 19CBA	875.0	869.3	-5.7
B-01-01 19BBA	877.0	868.7	-8.3
B-01-02 25BBC1	866.0	870.3	4.3
B-01-01 06BBA2	874.0	874.3	0.3
B-04-01 19BBA	837.0	858.7	21.7
B-01-01 18BDC2	870.0	872.4	2.4
B-01-01 18BAA	878.0	874.2	-3.8
B-04-01 19BDC	829.0	850.7	21.7
B-01-01 07CAA2	880.0	875.4	-4.6
B-02-01 31CAA2	863.0	873.7	10.7
B-04-01 18BAA	861.0	880.5	19.5
B-02-01 19BAA	819.0	822.1	3.1
B-02-01 06ABB3	787.0	787.0	0.0
B-02-01 07CAD	787.0	799.7	12.7
B-02-01 19DBB2	823.0	834.3	11.3
B-02-01 31ABB2	860.0	864.0	4.0
B-03-01 06BAA	802.0	833.3	31.3
B-02-01 07ABB	785.0	794.0	9.0
B-02-01 06ABB2	794.0	789.0	-5.0
B-02-01 06DBB1	778.0	789.8	11.8
B-01-01 30DBB	879.0	870.1	-8.9
B-01-01 07ABA2	886.0	877.7	-8.3
B-01-01 30ABA	880.0	868.6	-11.4
B-01-01 07DDC1	914.0	877.4	-36.6
B-04-01 30DCD	799.0	834.0	35.0
B-01-01 07DDC2	912.0	877.8	-34.2
B-02-01 19AAB2	818.0	826.9	8.9
B-02-01 19AAB2	819.0	826.8	7.8
B-01-01 07DDD	915.0	877.7	-37.3
B-01-01 29CBB	887.0	876.0	-11.0
B-03-01 29BBB	782.0	795.6	13.6
B-03-01 29BCC	755.0	795.2	40.2
B-02-01 32CBB	871.0	875.4	4.4
B-04-01 32BBC	794.0	831.1	37.1
B-03-01 32CBA	781.0	793.4	12.4
B-02-01 32BBA	870.0	869.9	-0.1
B-01-01 08BBA	886.0	878.3	-7.7
B-04-01 29BCA	809.0	832.0	23.0
B-01-01 29CAD	888.0	877.5	-10.5
B-01-01 07DDA	914.0	880.2	-33.8
B-03-01 32BAD	746.0	791.7	45.7
B-03-01 17DCC	741.0	807.0	66.0
B-03-01 32BAA	779.0	793.0	14.0
B-03-01 08ACC	782.0	805.4	23.4
B-04-01 32BDA	797.0	829.0	32.0
B-03-01 05ABB	833.0	826.9	-6.1
B-02-01 05ABC2	728.0	798.5	70.5
B-01-01 05ABA	889.0	879.3	-9.7
B-04-01 29DBB	799.0	828.8	29.8
B-04-01 29ADC	795.0	830.7	35.7
B-01-01 20DAC	890.0	877.2	-12.8
B-02-01 05AAB	733.0	800.4	67.4
B-01-01 29ADD	895.0	879.4	-15.6
B-01-01 29DDA2	891.0	882.8	-8.2
B-01-01 17AAD2	898.0	880.7	-17.3
B-01-01 20DAA	889.0	879.6	-9.4
B-03-01 16BBB1	709.0	791.6	82.6
B-02-01 08ADA	744.0	812.4	68.4
B-04-01 21BBB	808.0	836.2	28.2
B-02-01 09BCB1	730.0	814.3	84.3
B-01-01 28BAA	871.0	882.0	11.0
B-01-01 21CBA	891.0	882.3	-8.7
B-01-01 28BCA2	893.0	883.0	-10.0
B-01-01 28CDC	895.0	891.4	-3.6
B-04-01 33BAB	788.0	823.8	35.8
B-04-01 33BDB	788.0	823.2	35.2
B-04-01 28BAA	801.0	827.9	26.9
B-03-01 09DBB	768.0	805.7	37.7
B-04-01 33ACC	784.0	823.1	39.1
B-03-01 16DBB2	730.0	792.1	62.1
B-02-01 04DCB	720.0	812.9	92.9
B-04-01 21BAA	822.0	834.8	12.8
B-01-01 04ABA2	838.0	879.1	41.1
B-03-01 16DAB	830.0	798.0	-32.0
B-01-01 28AAB	897.0	888.3	-8.7

A-01-01 13ADA	951.0	938.5	-12.5
B-01-04 16DBA	877.0	902.0	25.0
B-01-03 14DBB	842.0	866.9	24.9
A-01-02 13ABD2	985.0	962.9	-22.1
A-01-03 18BBC	987.0	968.4	-18.6
A-01-02 14BBC	966.0	947.0	-19.0
A-01-02 14AAD	975.0	954.0	-21.0
B-01-02 18ACC	857.0	869.5	12.5
A-01-02 18ACB	949.0	939.6	-9.4
B-01-01 15BAD	900.0	895.2	-4.8
A-01-03 18BBB2	989.0	965.1	-23.9
A-01-03 08CDD	1004.0	993.6	-10.4
A-01-01 16AAA	932.0	927.0	-5.0
B-01-02 14BAD	877.0	879.3	2.3
A-01-01 17BBB	932.0	918.2	-13.8
A-01-01 15AAA	938.0	931.1	-6.9
A-01-02 09DCC	1001.0	944.5	-56.5
A-01-01 10CCC2	938.0	927.0	-11.0
B-01-02 13ABA	870.0	880.4	10.4
A-01-01 14BAB2	940.0	932.1	-7.9
A-01-01 14BAB1	946.0	932.1	-13.9
B-01-02 17BBC	865.0	870.6	5.6
A-01-02 09DDD	992.0	945.8	-46.2
A-01-02 07DCD	945.0	938.9	-6.1
B-01-01 10CCD	896.0	893.0	-3.0
A-01-01 07CCD	921.0	909.9	-11.1
B-01-01 18AAB	898.0	882.9	-15.1
B-01-01 10DCC	863.0	894.6	31.6
B-01-01 18BAA	887.0	881.4	-5.6
B-01-03 14AAB	836.0	867.0	31.0
B-01-02 13AAA	890.0	880.0	-10.0
A-01-02 07CCC2	947.0	934.9	-12.1
A-01-02 09CCC	953.0	938.5	-14.5
B-01-02 14BAA1	885.0	879.5	-5.5
B-01-01 07DDD	921.0	884.3	-36.7
B-01-02 16ABB	872.0	874.8	2.8
B-01-02 18AAB	884.0	870.0	-14.0
B-01-02 16BBB	856.0	873.2	17.2
B-01-01 07DDC1	919.0	883.7	-35.3
B-01-01 07DDA	916.0	886.5	-29.5
A-01-02 12CBC	974.0	952.4	-21.6
B-01-01 11CCB1	920.0	896.3	-23.7
A-01-02 11CBC2	970.0	949.5	-20.5
A-01-02 09CBC	949.0	937.9	-11.1
B-01-01 10DDB	908.0	894.9	-13.1
A-01-02 10CBC	956.0	939.5	-16.5
B-01-01 09DDB	900.0	890.4	-9.6
A-01-02 09DAC	984.0	944.7	-39.3
A-01-01 11CBC	933.0	928.7	-4.3
B-01-02 08DDA2	867.0	873.1	6.1
B-01-02 09CBC	866.0	873.4	7.4
B-01-02 12DAD	888.0	880.6	-7.4
A-01-01 12DBA2	951.0	931.3	-19.7
B-01-01 10CBB	903.0	890.7	-12.3
B-01-01 07CAA2	889.0	881.2	-7.8
A-01-03 09ADA	1020.0	1021.2	1.2
A-01-03 08BDA2	1000.0	991.4	-8.6
B-01-02 11BCC	857.0	877.1	20.1
A-01-01 11ADD	939.0	930.1	-8.9
B-01-02 09ACC	866.0	874.7	8.7
A-01-01 11ACB	945.0	928.0	-17.0
B-01-02 08BCC	855.0	870.5	15.5
A-01-01 09BAC	918.0	919.0	1.0
B-01-01 10BDA	900.0	891.5	-8.5
B-01-02 09ADA2	856.0	874.6	18.6
A-01-03 01DDD	1086.0	1092.6	6.6
A-01-01 09AAA	925.0	920.8	-4.2
A-01-03 08ABB1	1011.0	992.6	-18.4
A-01-02 12BAA	983.0	958.6	-24.4
A-01-02 11AAA	977.0	947.5	-29.5
A-01-01 10AAA2	931.0	924.4	-6.6
A-01-01 10AAA2	933.0	924.1	-8.9
B-01-01 11AAA	921.0	897.2	-23.8
A-01-01 09BBB2	925.0	915.5	-9.5
B-01-01 12AAA1	918.0	902.0	-16.0
B-01-01 12BAA2	911.0	898.9	-12.1
A-01-02 11BAB	972.0	945.8	-26.2
A-01-02 10ABA	963.0	944.4	-18.6
A-01-02 08BAA1	952.0	935.7	-16.3
A-01-02 09AAB2	957.0	940.6	-16.4
B-01-01 11AAB	920.0	896.9	-23.1
A-01-02 09BBB	954.0	938.2	-15.8
A-01-02 08BBB	945.0	934.2	-10.8
B-01-01 11BAB	919.0	894.8	-24.2
B-01-01 10AAA2	906.0	892.5	-13.5
A-01-02 07BBB	948.0	931.7	-16.3
A-01-01 12BBB	948.0	928.9	-19.1
B-01-01 08BBA	895.0	883.1	-11.9
B-01-01 07ABA2	894.0	881.2	-12.8
A-01-03 06DCD	999.0	979.4	-19.6
B-01-02 11ABB	877.0	876.5	-0.5
B-01-01 05CDC1	893.0	882.5	-10.5
B-01-02 09ABB	866.0	873.6	7.6
B-01-02 09BAA	854.0	873.6	19.6
B-01-02 09BBB2	858.0	873.1	15.1
A-01-01 02CCC	935.0	923.8	-11.2
B-01-02 08BBB2	854.0	870.4	16.4
B-01-02 03DCC	859.0	875.0	16.0
B-01-02 08ABB2	856.0	871.8	15.8
B-01-02 01CCC	853.0	876.8	23.8
B-01-02 02CCD	867.0	875.2	8.2
B-01-02 02CCC4	863.0	875.4	12.4
B-01-01 07DDC2	924.0	882.2	-41.8
A-01-02 01CAC	983.0	956.3	-26.7
B-01-01 03DAC	904.0	890.4	-13.6
A-01-01 04CAB	908.0	914.4	6.4
A-01-01 06CBB1	913.0	898.6	-14.4
B-01-01 01CAA	917.0	897.3	-19.7
B-01-02 02DBA	861.0	875.2	14.2
A-01-02 02BCC	966.0	949.0	-17.0
A-01-03 01ADA2	1097.0	1092.2	-4.8
B-01-01 04BCC	896.0	885.1	-10.9
B-01-02 04DBB2	847.0	872.7	25.7
B-01-02 05CBB	848.0	868.8	20.8
A-01-01 03BDB	923.0	918.5	-4.5
A-01-01 03BDB	925.0	918.1	-6.9
B-01-01 01BAC	909.0	895.8	-13.2
A-01-01 04BAC	909.0	913.2	4.2
A-01-03 05BAA	1011.0	992.4	-18.6
A-01-03 02AAB	1060.0	1058.8	-1.2

B-01-04 24AAA	846.0	845.9	-0.1
B-01-03 16CCC	847.0	856.3	9.3
B-01-04 19BBB1	928.0	913.2	-14.8
A-01-01 14DDA	953.0	949.9	-3.1
B-01-01 15CCB	906.0	896.1	-9.9
B-01-04 19AAA	927.0	902.2	-24.8
B-01-01 13DBC	929.0	915.5	-13.5
B-01-04 19BAA	924.0	908.3	-15.7
B-01-02 14CDA	876.0	875.4	-0.6
B-01-02 14DDB	879.0	875.9	-3.1
B-01-01 16DBD	901.0	893.3	-7.7
A-01-01 14DAB	952.0	946.4	-5.6
A-01-02 16DBB2	965.0	953.3	-11.7
A-01-02 15BCC2	967.0	953.9	-13.1
A-01-02 17ADD	965.0	951.9	-13.1
A-01-02 15ACC	969.0	954.9	-14.1
A-01-02 17CAA	961.0	951.0	-10.0
A-01-01 15DAA	947.0	946.0	-1.0
B-01-01 18BDC2	882.0	878.8	-3.2
B-01-02 14CAA	869.0	874.8	5.8
B-01-02 17CAA	858.0	864.0	6.0
B-01-02 17CBB	857.0	862.6	5.6
A-01-01 13ADA	958.0	948.4	-9.6
B-01-04 16DBA	870.0	892.5	22.5
A-01-02 13ABD2	986.0	965.9	-20.1
A-01-01 18ACB	924.0	922.5	-1.5
A-01-03 18BBC	988.0	971.2	-16.8
A-01-03 18BBC	987.0	971.2	-15.8
A-01-02 14BBC	972.0	954.5	-17.5
A-01-02 14AAD	977.0	960.1	-16.9
B-01-02 18ACC	851.0	861.6	10.6
A-01-02 18ACB	958.0	948.4	-9.6
B-01-01 16ADB	904.0	892.7	-11.3
B-01-02 13BCA	884.0	875.9	-8.1
B-01-02 18ADB	856.0	862.1	6.1
B-01-02 18ADA	851.0	862.3	11.3
B-01-01 15BAD	904.0	897.2	-6.8
B-01-01 16AAC	902.0	892.5	-9.5
A-01-03 18BBB2	987.0	967.4	-19.6
B-01-01 17AAD2	897.0	887.9	-9.1
B-01-01 17AAD2	897.0	887.9	-9.1
A-01-01 16AAA	928.0	938.1	10.1
A-01-01 17BBB	935.0	928.1	-6.9
A-01-01 15AAA	944.0	940.9	-3.1
A-01-02 09DCC	981.0	952.1	-28.9
A-01-01 10CCC2	943.0	938.0	-5.0
B-01-01 16AAB	907.0	892.5	-14.5
A-01-01 14BAB2	947.0	942.7	-4.3
A-01-01 14BAB1	952.0	941.8	-10.2
A-01-02 09DDD	988.0	953.1	-34.9
B-01-01 10CCD	900.0	894.5	-5.5
A-01-01 07CCD	925.0	917.9	-7.1
B-01-01 18AAB	892.0	880.4	-11.6
B-01-01 18BAA	885.0	878.0	-7.0
B-01-03 14AAB	829.0	857.7	28.7
B-01-02 13AAA	878.0	876.2	-1.8
A-01-02 07CCC2	954.0	944.7	-9.3
B-01-02 14BAA1	869.0	873.5	4.5
B-01-02 16ABB	865.0	867.0	2.0
B-01-02 16BBB	852.0	864.9	12.9
B-01-01 11CCB2	922.0	899.8	-22.2
A-01-02 12CBC	977.0	959.3	-17.7
B-01-01 11CCB1	923.0	899.5	-23.5
A-01-02 11CBC2	976.0	956.3	-19.7
A-01-02 09CDB	980.0	950.7	-29.3
A-01-02 09CBC	957.0	946.4	-10.6
A-01-02 10CCB	965.0	948.1	-16.9
A-01-01 09DAD	938.0	936.3	-1.7
B-01-01 09DDB	906.0	891.2	-14.8
A-01-02 09DAC	988.0	952.2	-35.8
A-01-01 11CBC	941.0	939.9	-1.1
B-01-02 08DDA2	858.0	864.2	6.2
B-01-01 10CBD	893.0	893.4	0.4
B-01-02 12DAD	876.0	876.2	0.2
A-01-02 08DAA	961.0	945.2	-15.8
A-01-01 08CAB	938.0	927.6	-10.4
A-01-01 12DBA2	958.0	941.3	-16.7
B-01-01 10CBB	904.0	892.2	-11.8
B-01-01 07CAA2	884.0	877.1	-6.9
A-01-03 09ADA	1017.0	1019.1	2.1
B-01-01 10ACD	908.0	896.0	-12.0
A-01-01 11ADD	947.0	940.7	-6.3
B-01-02 09ACC	856.0	865.2	9.2
A-01-01 11ACB	949.0	938.9	-10.1
B-01-02 08BCC	852.0	858.6	6.6
A-01-01 09BAC	930.0	930.6	0.6
B-01-01 10BDA	902.0	893.6	-8.4
B-01-02 09ADA2	847.0	864.8	17.8
A-01-03 01DDD	1089.0	1089.5	0.5
A-01-03 08ABB1	1012.0	993.1	-18.9
A-01-02 12BAA	983.0	964.9	-18.1
A-01-01 08BAA	926.0	926.2	0.2
A-01-02 11AAA	978.0	958.1	-19.9
B-01-01 11AAA	922.0	903.4	-18.6
A-01-01 09BBB2	927.0	928.5	1.5
B-01-01 12BAA2	918.0	908.1	-9.9
A-01-02 11BAB	975.0	955.1	-19.9
A-01-02 10ABA	967.0	952.1	-14.9
A-01-02 08BAA1	958.0	943.5	-14.5
A-01-02 09AAB2	962.0	947.4	-14.6
B-01-01 11AAB	921.0	902.5	-18.5
A-01-02 09BBB	960.0	945.7	-14.3
A-01-02 08BBB	956.0	942.4	-13.6
A-01-01 06CDD	925.0	915.8	-9.2
B-01-01 11BAB	923.0	899.3	-23.7
B-01-01 09AAB	904.0	888.9	-15.1
B-01-01 10AAA2	908.0	895.6	-12.4
A-01-02 07BBB	953.0	940.8	-12.2
A-01-01 12BBB	950.0	939.7	-10.3
A-01-01 10AAA1	939.0	934.9	-4.1
B-01-01 07ABA2	886.0	876.4	-9.6
B-01-01 07BBB	898.0	873.3	-24.7
A-01-03 06DCD	995.0	981.6	-13.4
B-01-02 11ABB	870.0	868.7	-1.3
B-01-02 10BBB3	860.0	864.5	4.5
B-01-01 05CDC1	888.0	879.1	-8.9
B-01-02 09ABB	856.0	862.8	6.8
B-01-02 09BBB2	850.0	861.7	11.7
A-01-01 02CCC	931.0	934.9	3.9
B-01-02 08BBB2	847.0	856.3	9.3

APPENDIX TABLE C-3

REFINED MODEL UNWEIGHTED CALIBRATION RESIDUALS - ENTIRE MODEL DOMAIN

B-04-01 28DBD	794.0	824.0	30.0
B-02-01 04DAA	811.0	815.4	4.4
B-02-01 27CBC	887.0	870.5	-16.5
B-03-01 27BBB	828.0	801.8	-26.2
B-03-01 22BBB2	747.0	809.7	62.7
B-03-01 15CBB1	831.0	805.6	-25.4
B-01-01 10BCC	897.0	883.6	-13.4
B-04-01 27CBB	793.0	827.4	34.4
B-04-01 34CBB	777.0	823.3	46.3
B-01-01 15CCB	899.0	888.1	-10.9
B-03-01 15CBB3	764.0	806.7	42.7
B-03-01 15BBB3	756.0	807.3	51.3
B-01-01 10CBD	897.0	884.9	-12.1
B-03-01 03BBB	776.0	824.0	48.0
B-01-01 10BDB	894.0	883.7	-10.3
B-01-01 10BDA	893.0	884.7	-8.3
B-01-01 15BAD	895.0	888.6	-6.4
B-03-01 22BAD	809.0	816.6	7.6
B-02-01 34CAA2	887.0	875.5	-11.5
B-03-01 34DBB1	823.0	811.8	-11.2
B-03-01 27ABB1	710.0	805.1	95.1
B-03-01 27ABB2	710.0	805.1	95.1
B-04-01 34ACB	788.0	822.6	34.6
B-04-01 22ABB	846.0	836.6	-9.4
B-01-01 22ACD	906.0	895.2	-10.8
B-01-01 03DBA	900.0	879.6	-20.4
B-01-01 27DAB2	897.0	907.2	10.2
B-01-01 03DAB	872.0	879.6	7.6
B-01-01 10DDB	883.0	888.7	5.7
B-01-01 10AAA2	897.0	885.5	-11.5
B-01-01 11CCB1	909.0	890.0	-19.0
B-02-01 34DDA	889.0	877.2	-11.8
B-02-01 26CBC2	874.0	869.3	-4.7
B-02-01 14CBB	852.0	852.3	0.3
B-03-01 26CBB2	707.0	817.6	110.6
B-03-01 26BBB	717.0	814.2	97.2
B-01-01 02BBB	894.0	881.1	-12.9
B-03-01 23BBB1	844.0	824.4	-19.6
B-04-01 23BBB	850.0	838.9	-11.1
B-03-01 35BBB	715.0	818.4	103.4
B-04-01 14BBB	888.0	850.3	-37.7
B-03-01 11BBB	779.0	815.3	36.3
B-01-01 11BAB	912.0	887.5	-24.5
B-04-01 23CAB	843.0	837.7	-5.3
B-03-01 26BAB	708.0	823.4	115.4
B-03-01 02ACC	780.0	814.7	34.7
B-03-01 26ABB	747.0	828.6	81.6
B-02-01 26ACA	857.0	865.4	8.4
B-02-01 14ABD2	815.0	849.4	34.4
B-01-01 11AAA	912.0	890.1	-21.9
B-02-01 35DAA	895.0	878.3	-16.7
B-03-01 14AAA	721.0	819.8	98.8
B-02-01 23DDD	841.0	858.4	17.4
B-01-01 02AAD2	921.0	888.1	-32.9
B-02-01 01CCC2	816.0	844.0	28.0
B-03-01 24BBB3	764.0	826.6	62.6
B-02-01 36BBC	875.0	875.7	0.7
B-02-01 24BBD	847.0	857.2	10.2
B-02-01 25BBB	838.0	860.0	22.0
B-04-01 12BCB	927.0	886.1	-40.9
B-02-01 36CBA2	914.0	888.9	-25.1
B-02-01 12BAC	788.0	854.8	66.8
B-02-01 12BDD3	844.0	850.5	6.5
B-01-01 25BAA	915.0	914.4	-0.6
B-01-01 12BAA2	913.0	891.4	-21.6
B-01-01 01CAA	913.0	889.0	-24.0
B-01-01 13DBC	920.0	902.8	-17.2
B-01-01 24ABB	911.0	904.1	-6.9
B-02-01 36BAA	867.0	881.7	14.7
B-02-01 13BAD	845.0	853.0	8.0
B-04-01 24DBB	839.0	848.1	9.1
B-02-01 12ABC2	967.0	860.1	-106.9
B-02-01 25ADC	862.0	876.3	14.3
B-01-01 12AAA1	906.0	893.1	-12.9
A-01-01 06CBB1	901.0	888.6	-12.4
A-02-01 30CBB	864.0	870.8	6.8
A-01-01 07CCD	911.0	899.6	-11.4
A-04-01 30CCB	829.0	836.1	7.1
A-04-01 06BBC	1048.0	993.7	-54.3
A-03-01 19CCD	797.0	834.7	37.7
A-04-01 31BBA2	797.0	827.5	30.5
A-01-01 30BAA1	907.0	920.0	13.0
A-03-01 18CDD1	755.0	822.5	67.5
A-03-01 18CDD2	779.0	822.4	43.4
A-03-01 07BAD	731.0	815.0	84.0
A-01-01 19ABB	924.0	911.4	-12.6
A-02-01 30CAA2	864.0	867.7	3.7
A-03-01 30BAA	804.0	835.2	31.2
A-04-01 30BDD	846.0	843.8	-2.2
A-03-01 19ACB	794.0	827.0	33.0
A-03-01 18DCB	784.0	819.6	35.6
A-04-01 30BAD	859.0	845.0	-14.0
A-04-01 31ABB	796.0	820.3	24.3
A-01-01 19DCD1	926.0	921.6	-4.4
A-01-01 30AAC1	924.0	924.9	0.9
A-03-01 31ACA	832.0	854.7	22.7
A-01-01 30AAC2	909.0	925.0	16.0
A-02-01 30DAA2	862.0	872.7	10.7
A-02-01 30DDD2	871.0	876.8	5.8
A-02-01 20CCC2	866.0	869.4	3.4
A-02-01 20BCC2	869.0	866.2	-2.8
A-02-01 20BBB	869.0	860.3	-8.7
A-04-01 30AAA1	805.0	842.3	37.3
A-04-01 30AAB2	800.0	843.3	43.3
A-03-01 29BBB	829.0	845.6	16.6
A-03-01 20BBB	815.0	827.2	12.2
A-04-01 32CCB	778.0	810.0	32.0
A-04-01 18DAA	825.0	867.5	42.5
A-05-01 32CBB	1224.0	1117.7	-106.3
A-03-01 05BBB2	772.0	806.3	34.3
A-02-01 20CAC	869.0	870.0	1.0
A-02-01 17CAB2	871.0	862.5	-8.5
A-04-01 29BBA	795.0	844.5	49.5
A-04-01 32BAB	776.0	815.1	39.1
A-02-01 08CDD2	872.0	864.3	-7.7
A-02-01 29CAA2	868.0	876.1	8.1
A-04-01 08BAA	1010.0	928.6	-81.4
A-02-01 20DCC	867.0	873.4	6.4
A-03-01 08BAA	776.0	819.0	43.0
A-02-01 08CAA	880.0	863.0	-17.0

B-01-01 04ABA2	893.0	885.2	-7.8
A-01-02 01AAB1	1021.0	968.7	-52.3
A-01-01 03BBB	921.0	915.6	-5.4
A-01-01 04AAA2	926.0	916.6	-9.4
A-01-01 02BBB2	934.0	921.5	-12.5
B-01-01 03BAA	897.0	886.4	-10.6
A-01-01 03ABB2	924.0	918.8	-5.2
B-01-01 02BBB	902.0	887.8	-14.2
B-02-01 36CDD	910.0	894.6	-15.4
A-02-01 33CCC	919.0	910.1	-8.9
A-02-03 33DCC	1025.0	1012.1	-12.9
A-02-01 33CDD2	919.0	912.6	-6.4
B-01-02 01BAA	859.0	873.9	14.9
A-02-01 35DDD	937.0	925.7	-11.3
B-01-01 05ABA	888.0	880.8	-7.2
B-01-01 06BBA2	869.0	876.3	7.3
B-01-02 02BBB1	845.0	874.1	29.1
B-01-02 05AAA	847.0	869.8	22.8
B-01-02 02BBB2	841.0	871.9	30.9
A-02-01 32DDA	906.0	907.9	1.9
B-02-01 34DDA	896.0	885.2	-10.8
A-02-01 36DAD	940.0	929.5	-10.5
B-02-01 36CBB	902.0	888.1	-13.9
A-02-01 32DAB2	914.0	905.0	-9.0
A-02-02 32DAA	962.0	940.1	-21.9
A-02-01 33ACC	917.0	910.1	-6.9
B-02-01 34CAA2	890.0	880.3	-9.7
B-02-01 33BCC2	884.0	878.1	-5.9
B-02-01 32CBB	868.0	875.2	7.2
B-02-01 31CAA2	854.0	870.4	16.4
B-02-02 36CAA	848.0	859.5	11.5
B-02-02 36BCC	815.0	859.2	44.2
A-02-03 35BBC	1065.0	1049.3	-15.7
B-02-01 36BBC	895.0	885.1	-9.9
A-02-01 32AAC	913.0	904.8	-8.2
A-02-03 35AAD	1109.0	1075.3	-33.7
A-02-02 31ADA	952.0	934.5	-17.5
A-02-04 30CDD	1175.0	1118.6	-56.4
A-02-03 36AAA2	1156.0	1105.1	-50.9
B-02-01 36BAA	892.0	885.9	-6.1
A-02-02 32ABB	959.0	937.0	-22.0
A-02-01 34BBB2	920.0	912.6	-7.4
B-02-01 32AAA2	869.0	867.5	-1.5
A-02-01 30DDD2	902.0	897.5	-4.5
A-02-01 29DDD2	917.0	906.1	-10.9
B-02-01 27DCC	888.0	876.9	-11.1
B-02-01 31BBA2	832.0	855.9	23.9
B-02-02 36BBB3	813.0	849.8	36.8
B-02-02 34BAA	823.0	855.1	32.1
B-02-02 27CCC	826.0	854.9	28.9
A-02-02 26CDB	1001.0	956.1	-44.9
A-02-02 27DCB1	985.0	951.0	-34.0
A-02-02 27DCB2	985.0	950.9	-34.1
B-02-01 27CBC	885.0	871.3	-13.7
A-02-03 25CBB	1132.0	1085.3	-46.7
B-02-01 26CBC2	879.0	873.7	-5.3
A-02-04 30ACC1	1194.0	1130.4	-63.6
A-02-01 30CBB	895.0	886.4	-8.6
A-02-01 30DAA2	905.0	894.1	-10.9
A-02-01 30CAA2	900.0	887.0	-13.0
A-02-01 29CAA2	909.0	900.1	-8.9
A-02-04 30ADD	1209.0	1145.6	-63.4
A-02-02 30DBB	948.0	932.5	-15.5
B-02-01 25ADC	891.0	882.4	-8.6
B-02-01 30CAA2	821.0	846.8	25.8
A-02-02 28BDD	979.0	944.2	-34.8
A-02-02 26BDC	991.0	958.2	-32.8
A-02-02 29ACC	964.0	937.2	-26.8
B-02-02 25DAA2	815.0	841.6	26.6
B-02-02 25CBB2	786.0	839.6	53.6
A-02-02 25BCA	1005.0	968.2	-36.8
A-02-02 27ACB	985.0	951.3	-33.7
B-02-01 26ACA	871.0	871.0	0.0
A-02-02 29BCB	958.0	934.5	-23.5
A-02-02 30BAD1	951.0	932.4	-18.6
A-02-02 30BAD2	950.0	932.3	-17.7
A-02-03 25BBB2	1144.0	1090.2	-53.8
A-02-04 20CCC	1226.0	1147.1	-78.9
B-02-01 25BBB	844.0	867.6	23.6
A-02-03 22DDD	1106.0	1062.8	-43.2
B-02-01 26AAA	853.0	864.7	11.7
A-02-02 28ABB1	979.0	944.4	-34.6
A-02-02 28ABB2	977.0	944.3	-32.7
A-02-01 28AAA1	929.0	913.3	-15.7
A-02-01 27ABB	931.0	916.6	-14.4
A-02-02 30BAB	948.0	931.3	-16.7
A-02-01 20DDD2	923.0	903.6	-19.4
A-02-01 20CCC2	908.0	892.3	-15.7
B-02-01 29BAB	837.0	847.6	10.6
B-02-02 26AAA	787.0	827.5	40.5
B-02-01 23DCC	840.0	865.9	25.9
B-02-02 25AAA2	798.0	828.6	30.6
B-02-02 27AAA	810.0	835.8	25.8
A-02-03 20DDA1	1059.0	1017.6	-41.4
A-02-03 20DDA2	1059.0	1017.6	-41.4
B-02-02 28AAA	810.0	843.7	33.7
B-02-02 25ABB2	781.0	824.7	43.7
A-02-01 23CCC	932.0	918.4	-13.6
B-02-02 28ABB	795.0	847.6	52.6
A-02-01 20DCC	912.0	898.7	-13.3
B-02-02 24CCC	784.0	825.6	41.6
B-02-01 23DCB	841.0	864.2	23.2
A-02-01 23DDA	939.0	923.3	-15.7
B-02-02 20DDD2	784.0	844.4	60.4
A-02-01 20CAC	908.0	895.7	-12.3
A-02-02 19CCB	945.0	930.3	-14.7
A-02-03 21DAA2	1083.0	1039.7	-43.3
A-02-02 22DAA	1007.0	957.8	-49.2
A-02-01 24DBA	945.0	928.9	-16.1
A-02-03 20ADD2	1075.0	1022.1	-52.9
A-02-01 20DAA	927.0	904.9	-22.1
B-02-01 23DBB	838.0	862.0	24.0
A-02-02 20ADD	972.0	942.4	-29.6
A-02-01 20BCC2	911.0	890.9	-20.1
A-02-03 20BCC2	1068.0	1004.6	-63.4
A-02-03 19BCD	1065.0	991.2	-73.8
B-02-01 20BCC	795.0	827.9	32.9
B-02-01 20BCC	797.0	827.9	30.9
B-02-02 24DBB2	770.0	813.0	43.0
A-02-03 24ADA	1193.0	1124.0	-69.0

B-01-02 08BBB1	856.0	856.1	0.1
B-01-02 03DCC	851.0	865.7	14.7
B-01-02 08ABB2	851.0	858.4	7.4
B-01-02 01CCC	847.0	869.2	22.2
B-01-02 02CCD	859.0	866.7	7.7
B-01-02 02CCC4	855.0	866.5	11.5
A-01-02 01CAC	983.0	963.2	-19.8
B-01-01 03DAC	901.0	893.1	-7.9
A-01-01 06CBB2	918.0	910.2	-7.8
B-01-01 01CAB	918.0	903.4	-14.6
A-01-01 06CBB1	928.0	909.0	-19.0
B-01-01 01CAA	919.0	905.4	-13.6
A-01-01 06DAA	918.0	919.8	1.8
B-01-01 02DAA	915.0	899.7	-15.3
B-01-01 04CAA	894.0	886.0	-8.0
A-01-02 02BCC	972.0	956.3	-15.7
A-01-03 01ADA2	1105.0	1089.8	-15.2
B-01-01 04BCC	893.0	883.3	-9.7
B-01-02 03DBB	848.0	863.6	15.6
B-01-02 05CBB	839.0	853.1	14.1
B-01-01 01BDA	913.0	901.9	-11.1
B-01-01 02BCB	902.0	891.3	-10.7
A-01-01 03BDB	929.0	928.9	-0.1
B-01-01 01BAC	913.0	902.8	-10.2
A-01-03 05ABD	1012.0	997.0	-15.0
A-01-03 05BAA	1007.0	993.0	-14.0
B-01-01 01BAD	914.0	902.4	-11.6
B-01-02 04ACA1	833.0	859.9	26.9
A-01-03 02AAB	1064.0	1062.5	-1.5
B-01-01 04ABA2	892.0	884.7	-7.3
B-01-01 04AAB	891.0	885.0	-6.0
A-01-01 03BBB	924.0	925.8	1.8
A-01-01 04AAA2	927.0	926.6	-0.4
A-01-01 02BBB2	936.0	932.0	-4.0
B-01-01 03BAA	897.0	887.6	-9.4
A-01-01 03ABB2	919.0	929.0	10.0
B-01-01 02BBB	901.0	890.4	-10.6
B-02-01 36CDD	911.0	901.4	-9.6
A-02-01 33CDD2	918.0	923.0	5.0
A-02-01 35DDD	938.0	935.9	-2.1
B-01-01 05ABA	881.0	877.2	-3.8
B-01-01 05BBB2	878.0	873.8	-4.2
B-01-01 06BBA2	858.0	868.7	10.7
B-01-02 01BBB2	826.0	862.6	36.6
B-01-02 05AAA	842.0	854.0	12.0
B-01-02 03ABB2	816.0	860.6	44.6
B-01-02 03BBB	819.0	858.7	39.7
A-02-01 32DDA	909.0	919.7	10.7
B-02-01 34DDA	894.0	886.6	-7.4
A-02-01 36DAD	944.0	938.6	-5.4
A-02-01 31DAA	916.0	913.4	-2.6
A-02-01 32DAB2	914.0	914.8	0.8
A-02-02 32DAA	964.0	947.2	-16.8
A-02-01 33ACC	918.0	919.9	1.9
B-02-01 34CAA2	889.0	880.4	-8.6
A-02-01 34BCC2	919.0	922.9	3.9
B-02-01 33BCC2	886.0	876.1	-9.9
B-02-01 32CBB	860.0	864.4	4.4
B-02-01 36ACD	905.0	900.4	-4.6
B-02-01 33BDD2	888.0	876.9	-11.1
B-02-02 36CAA	822.0	845.8	23.8
B-02-02 32CBA	831.0	843.6	12.6
A-02-01 32ACA	914.0	915.9	1.9
A-02-03 35BBC	1062.0	1050.3	-11.8
A-02-01 32AAC	914.0	914.9	0.9
A-02-02 31ADA	954.0	942.3	-11.7
B-02-01 35ABD	895.0	885.1	-9.9
A-02-03 36AAA2	1157.0	1099.8	-57.2
B-02-01 36BAA	895.0	891.4	-3.6
A-02-02 32ABB	960.0	944.5	-15.5
A-02-01 34BBB2	920.0	921.0	1.0
B-02-01 32BBA	865.0	853.4	-11.6
B-02-01 36BBA3	891.0	886.1	-4.9
B-02-01 32AAA2	881.0	866.5	-14.5
B-02-01 35AAB	891.0	883.7	-7.3
A-02-01 30DDD2	904.0	907.4	3.4
A-02-01 29DDD2	915.0	916.1	1.1
B-02-01 27DCC	887.0	875.5	-11.5
A-02-04 30CCA	1170.0	1106.5	-63.5
B-02-01 31ABB2	833.0	842.3	9.3
B-02-02 35BBB	814.0	835.9	21.9
B-02-02 34BAA	828.0	835.9	7.9
B-02-02 27CCC	802.0	837.0	35.0
A-02-02 27DCB1	985.0	956.5	-28.5
A-02-02 27DCB2	987.0	956.4	-30.6
B-02-01 27CBC	887.0	870.7	-16.3
A-02-03 28CAA	1040.0	1018.0	-22.0
A-02-03 25CBB	1132.0	1083.8	-48.2
B-02-01 26CBC2	877.0	872.7	-4.3
A-02-04 30ACC1	1192.0	1125.3	-66.7
A-02-01 30CBB	888.0	893.4	5.4
A-02-01 30CAA2	895.0	895.3	0.3
A-02-01 29CAA2	907.0	909.6	2.6
A-02-04 30ADD	1194.0	1141.5	-52.5
A-02-02 30DBB	947.0	939.4	-7.6
B-02-01 30CAA2	803.0	827.0	24.0
A-02-01 26DAA	938.0	932.5	-5.5
A-02-02 29ACC	963.0	944.0	-19.0
B-02-02 25DAA2	787.0	819.3	32.3
B-02-02 25CAA	720.0	813.6	93.6
B-02-02 25CBB2	780.0	815.2	35.2
A-02-02 25BCA	1004.0	970.6	-33.4
B-02-02 28DBB	813.0	831.4	18.4
B-02-01 25BCB	874.0	876.3	2.3
A-02-01 25BCA2	935.0	933.8	-1.2
A-02-02 27ACB	988.0	956.7	-31.3
B-02-01 26ACA	871.0	873.3	2.3
A-02-01 25BCA1	934.0	933.7	-0.3
B-02-01 25ACA	879.0	886.7	7.7
A-02-02 30BAD1	948.0	938.8	-9.2
A-02-02 30BAD2	947.0	938.7	-8.3
A-02-03 25BBB2	1135.0	1090.2	-44.8
A-02-04 20CCC	1224.0	1143.5	-80.5
B-02-01 25BBB	852.0	872.4	20.4
A-02-03 22DDD	1097.0	1063.2	-33.8
A-02-02 28ABB1	978.0	950.5	-27.5
A-02-02 28ABB2	976.0	950.3	-25.7
A-02-01 28AAA1	915.0	922.2	7.2
A-02-01 27ABB	929.0	925.0	-4.0
A-02-02 30BAB	942.0	937.7	-4.3

APPENDIX TABLE C-3

REFINED MODEL UNWEIGHTED CALIBRATION RESIDUALS - ENTIRE MODEL DOMAIN

A-03-01 32DBB	866.0	865.0	-1.0
A-03-01 05ABB2	776.0	815.1	39.1
A-03-01 17ABB2	800.0	826.7	26.7
A-04-01 32ABB	776.0	819.1	43.1
A-02-01 32DAB2	880.0	882.0	2.0
A-04-01 32ABA	784.0	821.6	37.6
A-02-01 32DDA	895.0	886.2	-8.8
A-01-01 17DAA	927.0	912.3	-14.7
A-01-01 09BBB2	899.0	897.8	-1.2
A-02-01 29DDD2	878.0	881.2	3.2
A-02-01 20DDD2	871.0	875.8	4.8
A-02-01 20DAA	877.0	871.1	-5.9
A-02-01 08DDD	874.0	871.6	-2.4
A-02-01 17DDD2	879.0	874.1	-4.9
A-02-01 04CBB2	903.0	872.7	-30.3
A-02-01 09CBB2	890.0	868.4	-21.6
A-02-01 33CCC	881.0	888.4	7.4
A-03-01 21CBB	859.0	851.9	-7.1
A-03-01 09BBC	796.0	826.4	30.4
A-01-01 28CAC	937.0	940.0	3.0
A-05-01 33BCC	1174.0	1103.8	-70.2
A-02-01 33CDD2	887.0	889.8	2.8
A-02-01 33ACC	882.0	885.0	3.0
A-04-01 21CDD	778.0	843.2	65.2
A-03-01 04BAA2	791.0	823.1	32.1
A-03-01 04DBB	796.0	826.9	30.9
A-04-01 30BCD	846.0	830.1	-15.9
A-01-01 16AAA	912.0	908.6	-3.4
A-04-01 28AAB	782.0	843.1	61.1
A-01-01 21AAA	911.0	919.8	8.8
A-01-01 21DDA3	923.0	931.4	8.4
A-01-01 21DDA2	934.0	931.8	-2.2
A-01-01 10CCC2	919.0	909.4	-9.6
A-02-01 34BCC2	886.0	887.6	1.6
A-02-01 28AAA1	885.0	883.8	-1.2
A-01-01 03BBB	889.0	892.1	3.1
A-02-01 34BBB2	882.0	884.4	2.4
A-02-01 09DDD2	901.0	876.9	-24.1
A-02-01 15CBB	899.0	875.7	-23.3
A-03-01 33DDD	915.0	889.7	-25.3
A-03-01 16DAA	830.0	861.1	31.1
A-03-01 04DDD2	793.0	840.9	47.9
A-04-01 27BAB2	772.0	848.1	76.1
A-01-01 22CDA	926.0	932.9	6.9
A-04-01 34BDD2	788.0	841.0	53.0
A-04-01 22DBB	791.0	848.4	57.4
A-01-01 15AAA	923.0	915.5	-7.5
D-01-01 03ADD	954.0	956.7	2.7
D-01-01 02BBC	942.0	956.2	14.2
A-01-01 11CBC	920.0	911.3	-8.7
A-01-01 35CCC	948.0	955.1	7.1
A-01-01 02CCC	907.0	904.1	-2.9
A-02-01 14CCC	892.0	884.5	-7.5
A-04-01 22ADA	812.0	864.6	52.6
A-04-01 22AAA	812.0	865.9	53.9
A-03-01 02BBB	806.0	846.9	40.9
A-01-01 14BAB1	930.0	917.1	-12.9
A-02-01 14BBA	895.0	879.6	-15.4
A-04-01 14CBB	825.0	870.2	45.2
A-01-01 14BAB2	926.0	914.9	-11.1
A-01-01S26CAA	943.0	948.5	5.5
A-01-01 11ACB	923.0	909.5	-13.5
A-02-01 14ACC	894.0	883.9	-10.1
A-04-01 26BDC	829.0	865.2	36.2
A-03-01 35ABB	902.0	893.2	-8.8
A-01-01 23DBA2	934.0	932.2	-1.8
A-04-01 26BDD	831.0	866.3	35.3
A-04-01 35BAA	807.0	862.6	55.6
A-04-01 23BAD	819.0	859.0	40.0
A-01-01 23AAB	931.0	925.3	-5.7
A-01-01 26AAA	947.0	941.4	-5.6
A-01-01 23DDA	939.0	936.2	-2.8
A-01-01 11ADD	920.0	912.9	-7.1
A-01-01 12BBB	921.0	909.8	-11.2
A-02-01 35DDD	906.0	903.3	-2.7
A-02-01 11DDD2	910.0	891.2	-18.8
A-02-01 13CCC2	892.0	893.5	1.5
A-03-01 26DDD2	879.0	893.9	14.9
A-03-01 26ADD	882.0	891.8	9.8
A-03-01 23AAD	837.0	883.2	46.2
A-03-01 24CBB	872.0	887.2	15.2
A-01-01S25BBA	946.0	952.3	6.3
A-03-01 11DDA	869.0	879.8	10.8
A-01-01S25BAB	948.0	952.2	4.2
	823.0	877.7	54.7
A-03-01 12CDB	840.0	877.5	37.5
A-03-01 01CDC	794.0	870.5	76.5
A-03-01 25CDD	844.0	895.7	51.7
A-01-01 12DBA2	932.0	913.9	-18.1
A-01-01 24AAA	939.0	929.6	-9.4
D-01-01 13DDD1	977.0	965.8	-11.2
A-01-01 13ADA	933.0	922.5	-10.5
A-01-02 07CCC2	931.0	918.4	-12.6
A-02-01 36DAD	912.0	906.6	-5.4
A-01-02 07BBB	925.0	913.2	-11.8
A-02-02 19CCB	899.0	901.7	2.7
A-02-01 01DDA	892.0	906.0	14.0
A-03-02 30CCC2	913.0	897.7	-15.3
D-01-02 07CBA	976.0	963.0	-13.0
A-02-02 30BAB	910.0	903.7	-6.3
D-01-02 07DCC	974.0	962.4	-11.6
A-01-02 18ACB	934.0	923.3	-10.7
A-02-02 30DBB	914.0	907.4	-6.6
D-01-02 18DCD	978.0	966.6	-11.4
A-03-02 30BAA	897.0	900.2	3.2
A-03-02 07CAD	862.0	883.1	21.1
D-01-02 19DAA	982.0	969.6	-12.4
D-01-02 18ADD	984.0	966.2	-17.8
D-01-02 06ADD	957.0	956.8	-0.2
D-01-02 07ADD	984.0	962.7	-21.3
D-01-02 06DDD	965.0	960.5	-4.5
A-01-02 18DDD2	938.0	931.0	-7.0
A-01-02 29BBB	949.0	948.7	-0.3
A-01-02 08BBB	929.0	916.1	-12.9
A-02-02 31ADA	921.0	911.6	-9.4
A-02-02 18DDD	928.0	909.2	-18.8
A-02-02 29BCB	919.0	908.9	-10.1
A-03-02 31DDA	931.0	900.5	-30.5
A-03-02 30DAD	919.0	901.4	-17.6
A-03-02 19AAD2	899.0	902.8	3.8

B-02-01 24BBD	875.0	865.9	-9.1
A-02-03 22ABA	1104.0	1066.2	-37.8
A-02-02 24AAA	1075.0	989.8	-85.2
A-02-03 14DCD	1146.0	1090.6	-55.4
A-02-01 20BBB	911.0	888.1	-22.9
A-02-01 21AAA2	928.0	912.3	-15.7
A-02-03 18DDD2	1063.0	1009.2	-53.8
A-02-01 17DDD2	930.0	903.9	-26.1
A-02-01 13CCC2	939.0	925.5	-13.5
A-02-03 14DCA	1149.0	1092.4	-56.6
A-02-02 18DDD	962.0	936.8	-25.2
B-02-01 19AAB2	789.0	810.3	21.3
B-02-01 19BAA	788.0	805.9	17.9
B-02-01 19BBB2	769.0	801.6	32.6
B-02-02 24BAA	762.0	798.7	36.7
A-02-01 14CCC	939.0	918.4	-20.6
A-02-02 16DDC	981.0	950.0	-31.0
B-02-02 22AAA	787.0	818.5	31.5
B-02-02 22ABB	793.0	824.4	31.4
B-02-02 22BBB	784.0	827.4	43.4
B-02-02 21ABB	734.0	826.8	92.8
A-02-03 16DDA	1080.0	1049.6	-30.4
B-02-01 13CCA	887.0	867.7	-19.3
A-02-02 15DCA	998.0	958.3	-39.7
A-02-02 15DCA	998.0	958.3	-39.7
B-02-02 17DDD	781.0	823.4	42.4
A-02-02 14CBC2	1005.0	961.4	-43.6
A-02-03 13DAC2	1200.0	1120.6	-79.4
A-02-03 17CAA2	1066.0	1022.5	-43.5
A-02-02 14DBB	1024.0	968.5	-55.5
A-02-01 17CAB2	913.0	888.9	-24.1
A-02-03 17ADD	1074.0	1032.9	-41.1
A-02-01 15CBB	948.0	910.1	-37.9
A-02-01 14ACC	943.0	920.9	-22.1
B-02-01 18CBB2	759.0	790.2	31.2
A-02-02 17ADA	972.0	945.7	-26.3
A-02-02 17ACB	940.0	938.8	-1.2
B-02-01 13BAD	880.0	865.8	-14.2
B-02-01 14ABD2	853.0	857.6	4.6
B-02-01 14AAD	872.0	858.5	-13.5
B-02-01 14AAD	872.0	858.5	-13.5
A-02-01 14BBA	942.0	918.1	-23.9
A-02-01 18AAA1	901.0	878.2	-22.8
A-02-03 08DDD2	1056.0	1040.0	-16.0
A-02-01 08CDD2	913.0	889.9	-23.1
B-02-01 12CDD	879.0	863.7	-15.3
A-02-01 15ABB	947.0	915.5	-31.5
A-02-03 07DCC2	1079.0	1011.1	-67.9
A-02-01 11DDD2	950.0	927.2	-22.8
A-02-01 08DDD	923.0	902.6	-20.4
A-02-01 09DDD2	949.0	911.9	-37.1
B-02-02 16ABB	770.0	813.6	43.6
B-02-01 18BBB2	759.0	787.5	28.5
B-02-02 13ABB	756.0	787.5	31.5
B-02-02 13BBA	756.0	788.6	32.6
B-02-01 09CCC	706.0	817.8	111.8
B-02-02 14ABB	755.0	795.8	40.8
B-02-02 10DCC	766.0	812.0	46.0
B-02-01 08CDC	754.0	804.7	50.7
A-02-03 09CDA	1058.0	1055.1	-2.9
B-02-01 12CAD	881.0	861.1	-19.9
A-02-01 12DDA	961.0	935.7	-25.3
B-02-01 07CAD	761.0	790.6	29.6
B-02-01 08CAD	745.0	802.1	57.1
A-02-03 07DAB	1061.0	1021.2	-39.8
A-02-01 08CAA	916.0	889.0	-27.0
A-02-03 07CAA	1067.0	1014.0	-53.0
A-02-01 09CBB2	932.0	899.3	-32.7
B-02-01 12BDD3	871.0	859.5	-11.5
A-02-02 09ADD2	974.0	948.7	-25.3
B-02-01 09BDC	689.0	814.6	125.6
B-02-01 08DAB	761.0	806.3	45.3
B-02-01 07CBB1	755.0	785.1	30.1
B-02-01 08ADC	761.0	805.7	44.7
B-02-01 12BAC	899.0	859.4	-39.6
B-02-01 09BCB1	721.0	809.2	88.2
A-02-02 09BAD	956.0	942.6	-13.4
B-02-01 09BCB2	704.0	796.8	92.8
A-02-02 08BBC2	952.0	936.0	-16.0
A-02-02 08BBC1	946.0	935.7	-10.3
A-02-01 11BAA	947.0	928.4	-18.6
B-02-01 01CCC3	842.0	853.5	11.5
A-02-01 02DDD2	945.0	930.3	-14.7
B-02-01 01CCC2	869.0	852.3	-16.7
B-02-01 07ABB	758.0	785.0	27.0
B-02-02 10BAA	750.0	802.5	52.5
B-02-02 11BBB	755.0	794.5	39.5
B-02-01 04DCB	700.0	812.4	112.4
B-02-02 04DCB	836.0	807.0	-29.0
A-02-01 04CBB2	931.0	900.8	-30.2
A-02-01 06ACC	882.0	871.3	-10.7
A-02-02 04CAB	963.0	935.5	-27.5
B-02-01 06DBB3	760.0	780.1	20.1
B-02-01 06DBB1	758.0	779.7	21.7
B-02-01 05DBB	728.0	794.2	66.2
A-02-02 01ADB2	1014.0	994.0	-20.0
A-02-02 01ADB1	1034.0	993.6	-40.4
A-02-02 02ABC	995.0	962.4	-32.6
A-02-02 03AAD	990.0	951.5	-38.5
A-02-02 06ACB	928.0	926.2	-1.8
B-02-02 01ACB2	735.0	769.5	34.5
B-02-01 06BCB2	724.0	781.3	57.3
B-02-01 05ABD	781.0	797.1	16.1
B-02-01 05ABC2	718.0	794.4	76.4
A-03-01 33DDD	942.0	921.7	-20.3
A-02-02 05AAA	962.0	926.6	-35.4
A-03-01 34DDD2	923.0	920.7	-2.3
B-02-01 05AAB	715.0	797.8	82.8
B-02-01 06ABB3	758.0	777.0	19.0
A-03-01 35DDD	937.0	920.5	-16.5
B-02-02 01ABA	737.0	769.4	32.4
B-02-02 05AAB	842.0	805.9	-36.1
B-02-02 03AAA	764.0	788.9	24.9
B-02-02 03BBB	825.0	803.2	-21.8
A-03-01 36CCA	944.0	917.3	-26.7
A-03-02 31DDA	954.0	923.8	-30.2
A-03-01 32DBB	857.0	884.0	27.0
A-03-02 33DAA	966.0	927.7	-38.3
B-03-01 34DBB1	794.0	819.4	25.4
B-03-02 35CBB	784.0	785.8	1.8

A-02-01 20DDD2	920.0	913.5	-6.5
A-02-01 20CCC2	905.0	900.5	-4.5
B-02-02 26AAA	733.0	799.8	66.8
B-02-02 25AAA2	765.0	803.0	38.0
B-02-02 27AAA	776.0	811.6	35.6
A-02-01 23CCC	930.0	927.6	-2.4
A-02-01 20DCC	910.0	907.5	-2.5
B-02-01 23DDD	846.0	867.4	21.4
B-02-01 23DCB	844.0	866.0	22.0
A-02-01 23DDA	935.0	931.6	-3.4
A-02-01 20CAC	910.0	903.8	-6.2
A-02-02 19CCB	939.0	936.4	-2.6
A-02-03 21DAA2	1072.0	1038.7	-33.3
A-02-02 22DAA	995.0	960.2	-34.8
A-02-01 24DBA	938.0	934.9	-3.1
A-02-01 20DAA	922.0	913.8	-8.2
B-02-01 23DBB	852.0	864.3	12.3
A-02-02 20ADD	963.0	946.1	-16.9
A-02-01 20BCC2	908.0	898.9	-9.1
A-02-03 20BCC2	1059.0	1001.5	-57.5
B-02-01 19DBB2	770.0	793.6	23.6
B-02-01 20BCC	772.0	805.6	33.6
B-02-02 24DBB2	733.0	782.8	49.8
A-02-03 24ADA	1191.0	1125.3	-65.7
B-02-01 24BBD	872.0	867.3	-4.7
A-02-03 22ABA	1090.0	1067.8	-22.2
A-02-03 14DCD	1139.0	1095.7	-43.3
A-02-01 20BBB	909.0	896.0	-13.0
A-02-01 21AAA2	927.0	921.2	-5.8
A-02-03 18DDD2	1045.0	1005.5	-39.5
A-02-01 17DDD2	924.0	912.6	-11.4
A-02-01 13CCC2	914.0	931.3	17.3
A-02-03 14DCA	1143.0	1097.8	-45.2
A-02-02 18DDD	951.0	939.5	-11.5
B-02-02 24BBB3	731.0	772.1	41.1
B-02-01 19BBB2	731.0	772.3	41.3
B-02-02 24BAA	722.0	769.8	47.8
A-02-01 14CCC	935.0	926.9	-8.1
A-02-02 16DDC	969.0	950.0	-19.0
B-02-02 22ABB	765.0	798.1	33.1
B-02-02 22BBB	763.0	801.8	38.8
B-02-02 21ABB	764.0	802.3	38.3
A-02-03 16DDA	1062.0	1048.9	-13.1
B-02-02 17DDD	795.0	797.5	2.5
A-02-02 14CBC2	984.0	958.8	-25.2
A-02-03 13DAC2	1198.0	1125.5	-72.5
A-02-03 17CAA2	1045.0	1018.1	-26.9
A-02-02 14DBB	1007.0	964.4	-42.6
A-02-01 17CAB2	913.0	898.9	-14.1
A-02-03 17ADD	1037.0	1028.6	-8.4
A-02-01 15CBB	943.0	921.5	-21.5
B-02-01 14CBB	854.0	851.3	-2.7
A-02-01 14ACC	933.0	927.9	-5.1
B-02-01 18CBB2	723.0	760.9	37.9
A-02-02 17ADA	960.0	943.9	-16.1
A-02-02 17ACB	941.0	939.2	-1.8
B-02-01 13BAD	878.0	863.0	-15.0
B-02-01 14ABD2	800.0	850.7	50.7
A-02-01 17BAA1	918.0	902.9	-15.1
A-02-01 14BBA	938.0	926.6	-11.4
A-02-01 18AAA1	909.0	887.8	-21.2
A-02-03 08DDD2	1030.0	1034.8	4.8
A-02-01 08CDD2	916.0	900.3	-15.7
B-02-01 12CDD	879.0	859.2	-19.8
A-02-01 15ABB	943.0	924.8	-18.2
A-02-03 07DCC2	1061.0	1003.9	-57.1
A-02-01 08DDD	926.0	912.3	-13.7
A-02-01 09DDD2	946.0	921.6	-24.4
B-02-02 13BBA	711.0	752.2	41.2
B-02-01 09CCC	686.0	796.4	110.4
B-02-02 10DCC	739.0	784.2	45.2
A-02-03 09CDA	1027.0	1051.3	24.3
B-02-01 12CAD	873.0	855.0	-18.0
B-02-01 08CDB	733.0	777.8	44.8
A-02-01 12DDA	948.0	933.2	-14.8
B-02-01 08CAD	728.0	777.5	49.5
A-02-03 07DAB	1004.0	1012.8	8.8
A-02-01 08CAA	919.0	899.7	-19.3
A-02-03 07CAA	1047.0	1005.2	-41.8
B-02-01 12BCC	855.0	849.0	-6.0
A-02-01 09CBB2	933.0	908.3	-24.7
B-02-01 12BDD3	878.0	852.5	-25.5
A-02-02 09ADD2	976.0	938.8	-37.2
B-02-01 08ADC	739.0	779.4	40.4
B-02-01 12BAC	911.0	852.3	-58.7
B-02-01 09BCB1	696.0	782.2	86.2
A-02-02 09BAD	951.0	932.7	-18.3
B-02-01 08ADA	736.0	778.5	42.5
A-02-02 08BBC2	945.0	932.0	-13.0
A-02-01 11BAA	924.0	926.6	2.6
B-02-01 01CCC2	857.0	842.4	-14.6
B-02-02 10BAA	735.0	777.1	42.1
B-02-02 11BBB	726.0	767.2	41.2
A-02-01 01DDA	943.0	928.1	-14.9
A-02-02 05DBC	952.0	928.4	-23.6
B-02-02 04DCB	840.0	784.3	-55.7
B-02-01 04DAA	771.0	785.8	14.8
A-02-01 04CBB2	941.0	904.5	-36.5
A-02-01 06ACC	887.0	866.8	-20.2
A-02-02 06DBA	926.0	927.6	1.6
A-02-02 04CAB	933.0	923.0	-10.0
B-02-01 06DBB2	727.0	746.5	19.5
B-02-01 05DBB	709.0	759.3	50.3
A-02-02 01ADB2	979.0	975.0	-4.0
A-02-02 01ADB1	984.0	974.2	-9.8
A-02-02 02ABC	962.0	931.9	-30.1
A-02-02 03AAD	975.0	922.4	-52.6
A-02-02 06ACB	932.0	922.6	-9.4
B-02-01 06BCB2	659.0	748.2	89.2
B-02-01 05ABC2	736.0	757.3	21.3
B-02-02 02BBC	741.0	764.8	23.8
A-02-01 03BBA	947.0	913.0	-34.0
B-02-02 02BAD	730.0	756.5	26.5
A-03-01 33DDD	945.0	925.8	-19.2
A-02-02 05AAA	948.0	916.8	-31.2
A-03-01 34DDD2	916.0	924.2	8.2
B-02-01 05AAB	702.0	761.3	59.3
A-03-01 35DDD	934.0	920.9	-13.1
B-02-02 03BAA	761.0	772.9	11.9
B-02-02 05AAB	827.0	793.2	-33.8

APPENDIX TABLE C-3

REFINED MODEL UNWEIGHTED CALIBRATION RESIDUALS - ENTIRE MODEL DOMAIN

A-02-02 08BBC2	932.0	913.9	-18.1
A-01-02 32CCD	961.0	951.4	-9.6
A-03-02 06DAA	877.0	903.2	26.2
D-01-02 29BDD	989.0	979.3	-9.7
A-03-02 08BBA2	881.0	901.0	20.0
A-04-02 29BCD	869.0	913.2	44.2
D-01-02 17CDD	975.0	967.2	-7.8
D-01-02 20CDD	987.0	975.3	-11.7
D-01-02 20BDA	988.0	968.5	-19.5
D-01-02 20DCB	985.0	972.4	-12.6
D-01-02 08BAA1	971.0	966.1	-5.0
A-01-02 17CAA	937.0	927.0	-10.0
A-01-02 08BAA1	932.0	917.9	-14.1
A-02-02 32ABB	928.0	914.7	-13.3
A-02-02 29ACC	933.0	913.5	-19.5
A-02-02 17ACB	939.0	912.1	-26.9
A-03-02 17DCB	905.0	905.9	0.9
A-04-02 32BAA2	871.0	913.4	42.4
A-01-02 32AAA2	964.0	950.0	-14.0
A-01-02 17ADD	942.0	928.2	-13.8
A-01-02N29DDA	966.0	951.6	-14.4
A-01-02 09CBC	931.0	921.2	-9.8
A-01-02 09BBB	934.0	921.1	-12.9
A-02-02 32DAA	935.0	920.8	-14.2
A-02-02 17ADA	969.0	920.2	-48.8
A-03-02 29DDA2	932.0	906.9	-25.1
A-03-02 20AAA2	916.0	908.5	-7.5
A-01-02 33CBD	967.0	957.3	-9.7
A-01-02 09CDB	959.0	925.5	-33.5
A-02-02 04CAB	946.0	915.1	-30.9
A-01-02 16DBB2	940.0	930.2	-9.8
A-02-02 28BDD	947.0	925.5	-21.5
A-02-02 28ABB2	945.0	927.4	-17.6
A-02-02 28ABB1	948.0	926.2	-21.8
A-03-02 09DBB	911.0	909.6	-1.4
A-02-02 16DDD	961.0	929.1	-31.9
A-01-02 09AAB2	936.0	923.3	-12.7
D-01-02 10BBB	995.0	969.9	-25.1
A-01-02 09DDD	959.0	928.3	-30.7
A-01-02 15BCC2	943.0	930.6	-12.4
A-01-02 10CBC	940.0	923.8	-16.2
A-02-02 09ADD2	954.0	932.9	-21.1
A-03-02 09DAA	905.0	910.3	5.3
A-03-02 33DAA	920.0	920.4	0.4
A-03-02 16DAA	932.0	914.5	-17.5
D-01-02 03CBA	980.0	975.5	-4.5
A-03-02 10BDC	906.0	910.9	4.9
A-01-02 15ACC	947.0	930.8	-16.2
A-02-02 27ACB	961.0	937.0	-24.0
A-03-02 22BAA	948.0	918.2	-29.8
A-03-02 22DBB	959.0	919.9	-39.1
A-02-02 15DCA	975.0	943.0	-32.0
A-03-02 15ACD	928.0	917.7	-10.3
A-03-02 03AAB	895.0	918.2	23.2
A-04-02 22AAB	901.0	912.2	11.2
A-01-02 14BBC	949.0	929.1	-19.9
A-01-02 11CBC2	952.0	931.7	-20.3
A-01-02 14CCB	954.0	934.1	-19.9
A-03-02 15DDD	941.0	920.7	-20.3
A-02-02 14CBC2	988.0	946.7	-41.3
A-03-02 26CBC2	979.0	930.7	-48.3
A-03-02 26CCA	987.0	933.6	-53.4
A-04-02 26CBA	896.0	912.5	16.5
A-01-02 11BAB	952.0	930.9	-21.1
A-01-02 14CDD	958.0	936.6	-21.4
D-01-02 02DCC2	1014.0	980.5	-33.5
A-02-02 02ABC	994.0	957.4	-36.6
A-03-02 26BAA2	974.0	930.5	-43.5
A-03-02 26DCB	985.0	938.6	-46.4
A-01-02 11AAA	956.0	933.7	-22.3
A-04-02 35AAB	904.0	921.5	17.5
A-01-02 26AAA	976.0	956.7	-19.3
A-01-02 35DDD	986.0	977.3	-8.7
A-01-02 14AAD	957.0	934.1	-22.9
A-01-02 26DDD	985.0	968.3	-16.7
A-01-02 12CBC	956.0	933.8	-22.2
A-04-02 11ADB	1065.0	1007.5	-57.5
A-03-02 26AAD	985.0	936.9	-48.1
A-03-02 24CCB	965.0	932.7	-32.3
A-01-02 01CAC	968.0	940.0	-28.0
A-03-02 24BAB2	947.0	922.9	-24.1
A-01-02 12BAA	964.0	942.2	-21.8
A-03-02 25BDA	992.0	943.1	-48.9
A-02-02 12ACB	1044.0	983.7	-60.3
A-03-02 25DBC1	990.0	947.9	-42.1
A-01-03 18BBC	968.0	948.0	-20.0
A-03-03 30CBC	997.0	943.8	-53.2
A-02-03 19BCD	1053.0	977.4	-75.6
A-04-03 07BCD1	1081.0	1064.7	-16.3
A-04-03 06BCD	1166.0	1172.9	6.9
A-02-03 07CAA	1068.0	1000.8	-67.2
A-03-03 30CDA	1011.0	969.0	-42.0
A-02-03 07DCC2	1076.0	996.1	-79.9
A-02-03 07DAB	1034.0	1003.8	-30.2
A-01-03 31DDA	999.0	990.4	-8.6
D-01-03 06AAA	1017.0	993.2	-23.8
A-01-03 05BAA	993.0	976.6	-16.4
A-01-03 08CDD	986.0	974.1	-11.9
A-01-03 08BDA2	983.0	973.7	-9.3
A-01-03 08ABB1	988.0	974.7	-13.3
A-02-03 20DDA1	1044.0	1001.7	-42.3
A-02-03 20DDA2	1042.0	1001.7	-40.3
A-02-03 17ADD	1051.0	1016.1	-34.9
A-02-03 20ADD2	1056.0	1005.8	-50.2
A-02-03 09CDD	1054.0	1039.3	-14.7
A-02-03 09CDA	1051.0	1043.7	-7.3
A-02-03 09CDA	1052.0	1042.5	-9.5
A-01-03 33ADB	1010.0	1030.7	20.7
A-02-03 22ABA	1093.0	1055.3	-37.7
A-02-03 35BBC	1051.0	1033.1	-17.9
A-02-03 14DCD	1136.0	1084.7	-51.3
A-02-03 14DCA	1139.0	1086.7	-52.3
A-01-03 35ADD	1058.0	1076.8	18.8
A-01-03 36BCC	1046.0	1078.6	32.6
A-02-03 25BBB2	1132.0	1079.8	-52.3
A-02-03 25CBB	1125.0	1072.9	-52.1
A-02-03 13DAC2	1193.0	1113.5	-79.5
A-01-03 01ADA2	1089.0	1076.3	-12.7
A-01-03 01DDD	1076.0	1073.8	-2.2
A-01-04 30CDD	1081.0	1087.1	6.1

B-03-01 31BCC	727.0	770.0	43.0
A-03-02 34ADA	986.0	934.2	-51.8
A-03-02 36BDA	1002.0	965.0	-37.0
B-03-01 32BAD	717.0	787.8	70.8
A-03-01 35ABB	925.0	912.1	-12.9
B-03-01 35BBB	640.0	827.7	187.7
A-03-02 30CCC2	934.0	915.7	-18.3
A-03-01 25CDD	775.0	911.3	136.3
A-03-01 26DDD2	907.0	910.2	3.2
B-03-02 35AAA	750.0	777.6	27.6
B-03-02 36ABB	733.0	771.4	38.4
A-03-03 30CDA	1013.0	978.5	-34.5
A-03-01 27CCC	937.0	916.4	-20.6
B-03-02 35BBB	775.0	787.4	12.4
A-03-02 26DDB	986.0	937.5	-48.5
A-03-02 26CCA	987.0	929.2	-57.8
A-03-02 27DBB	971.0	925.6	-45.4
A-03-03 30CAC2	1003.0	964.3	-38.7
A-03-03 30CBC	997.0	955.9	-41.1
A-03-02 29DDA2	943.0	916.3	-26.7
A-03-02 25CAC	995.0	944.7	-50.3
A-03-02 26CBC2	977.0	926.2	-50.8
A-03-02 25DBC1	989.0	946.9	-42.1
A-03-02 30DAD	938.0	915.0	-23.0
B-03-01 26CBB2	701.0	828.9	127.9
A-03-01 26ADD	911.0	906.7	-4.3
B-03-01 29BCC	739.0	789.1	50.1
A-03-02 25BDA	991.0	938.0	-53.0
A-03-02 30ADA	931.0	912.1	-18.9
A-03-02 26AAD	983.0	928.9	-54.1
A-03-02 27BAD	972.0	916.8	-55.2
B-03-01 27ABC2	698.0	819.6	121.6
A-03-02 25BAB	983.0	929.0	-54.0
A-03-02 26BAA2	1007.0	922.0	-85.0
A-03-02 27BBB	955.0	913.6	-41.4
A-03-01 30BAA	831.0	847.5	16.5
B-03-01 26ABB	752.0	832.9	80.9
B-03-01 26BAB	704.0	829.3	125.3
A-03-01 19CCD	811.0	846.2	35.2
B-03-01 26BBB	722.0	828.1	106.1
A-03-01 25ABB	834.0	905.5	71.5
B-03-01 27ABB1	693.0	819.6	126.6
B-03-01 27ABB2	694.0	819.6	125.6
A-03-02 30BAA	921.0	910.8	-10.2
B-03-01 27BBB	804.0	810.4	6.4
B-03-02 25BAA	750.0	783.3	33.3
B-03-02 26BAA	787.0	791.9	4.9
A-03-02 24CCB	968.0	923.2	-44.8
B-03-02 27AAA	793.0	794.8	1.8
B-03-02 27ABB	802.0	800.7	-1.3
A-03-01 22DDA3	911.0	899.8	-11.2
A-03-01 19DBA	818.0	843.5	25.5
A-03-01 21CBB	857.0	866.0	9.0
A-03-01 21BDD	866.0	872.8	6.8
A-03-02 22DBB	1028.0	912.5	-115.5
A-03-01 24CBB	892.0	900.6	8.6
A-03-02 23BCC	950.0	914.4	-35.6
B-03-01 19CBB	796.0	788.3	-7.7
A-03-01 19ACB	813.0	839.6	26.6
B-03-01 22BCA	789.0	811.9	22.9
A-03-01 21ADA	877.0	880.8	3.8
A-03-02 19AAD2	921.0	906.9	-14.1
B-03-01 23BBC	745.0	819.9	74.9
A-03-02 20AAA2	896.0	908.1	12.1
A-03-01 20BBB	875.0	837.8	-37.2
A-03-02 24BAB2	930.0	911.3	-18.7
B-03-01 24BBB3	783.0	832.0	49.0
A-03-02 22BAA	940.0	910.4	-29.6
B-03-01 22ABB	691.0	814.6	123.6
B-03-02 23BAA	798.0	795.5	-2.5
B-03-02 21ABA	915.0	819.6	-95.4
B-03-02 22AAA	809.0	798.8	-10.2
A-03-02 15DDD	929.0	910.6	-18.4
A-03-01 18DCB	805.0	833.7	28.7
A-03-02 17DCB	916.0	905.0	-11.0
A-03-01 17DBC	830.0	829.3	-0.7
A-03-01 16DAA	793.0	866.4	73.4
A-03-02 16DAA	928.0	907.4	-20.6
A-03-02 14CAB	932.0	909.7	-22.3
A-03-01 17ACC	860.0	820.7	-39.3
B-03-01 16DBB3	723.0	785.8	62.8
B-03-01 15CBB3	729.0	805.4	76.4
A-03-02 15ACD	904.0	908.1	4.1
B-03-01 16DAB	723.0	791.3	68.3
B-03-01 16DBB2	739.0	785.7	46.7
B-03-01 16BCC	736.0	782.9	46.9
B-03-02 14BCB2	822.0	801.5	-20.5
B-03-01 13BAA2	660.0	830.4	170.4
B-03-01 14AAA	738.0	825.4	87.4
A-03-01 17ABB2	815.0	833.8	18.8
B-03-01 15BBB3	735.0	797.5	62.5
B-03-01 16BBB1	739.0	783.6	44.6
B-03-02 13BAA	838.0	791.1	-46.9
B-03-02 15AAA	816.0	803.3	-12.7
B-03-02 14BAA	809.0	799.7	-9.3
A-03-01 12CDB	815.0	887.5	72.5
A-03-01 11DDA	881.0	890.7	9.7
B-03-01 08CBC	784.0	792.9	8.9
A-03-02 07CAD	864.0	888.0	24.0
A-03-02 09DAA	878.0	899.4	21.4
A-03-02 09DBB	874.0	899.5	25.5
A-03-02 09CAA	910.0	899.9	-10.1
A-03-02 10DBA	910.0	902.0	-8.0
A-03-01 07DBA	793.0	826.5	33.5
A-03-02 08DAB	886.0	897.9	11.9
B-03-01 09DBB	757.0	802.4	45.4
A-03-02 10BDC	882.0	898.4	16.4
A-03-02 11BDC	909.0	907.0	-2.0
B-03-02 10BDC	850.0	821.6	-28.4
A-03-01 09BBC	760.0	829.1	69.1
A-03-01 12AAD	826.0	882.3	56.3
A-03-01 07BAD	786.0	822.7	36.7
B-03-01 12BBB2	763.0	816.0	53.0
A-03-01 08BAA	791.0	825.0	34.0
B-03-01 11BBB	804.0	811.8	7.8
A-03-02 08BBA2	864.0	893.7	29.7
A-03-01 04DDD1	784.0	841.8	57.8
A-03-02 03DDD	892.0	901.5	9.5
B-03-01 08ABB1	883.0	799.5	-83.5
B-03-01 07ABB	806.0	806.3	0.3

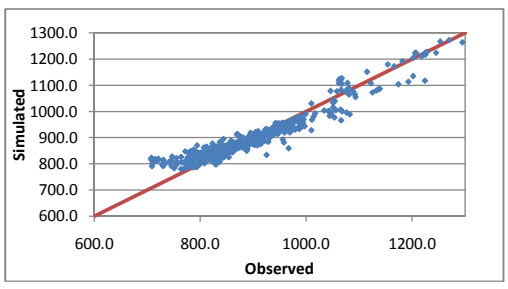
B-02-02 03AAA	748.0	763.5	15.5
B-02-02 03BBB	821.0	780.6	-40.4
A-03-02 31DDA	947.0	919.4	-27.6
A-03-01 32DBB	883.0	882.3	-0.7
A-03-02 33DAA	942.0	898.7	-43.3
B-03-01 34DBB1	777.0	788.1	11.1
B-03-01 32CBB	734.0	743.5	9.5
B-03-02 35CBB	778.0	763.5	-14.5
B-03-01 31BCC	718.0	735.0	17.0
A-03-02 34ADA	953.0	891.3	-61.7
A-03-02 36BDA	965.0	923.4	-41.6
B-03-01 32BAD	718.0	749.7	31.7
A-03-01 32ABA2	897.0	882.3	-14.7
A-03-01 35ABB	920.0	916.4	-3.6
B-03-01 35BBB	710.0	795.9	85.9
B-03-01 34BBB	710.0	775.7	65.7
A-03-02 30CCC2	932.0	915.0	-17.0
B-03-01 32BAA	733.0	751.3	18.3
B-03-02 35AAA	736.0	752.3	16.3
A-03-03 30CDA	976.0	940.4	-35.6
B-03-02 34BAA	780.0	774.8	-5.2
A-03-01 27CCC	938.0	919.4	-18.6
B-03-02 35BBB	769.0	766.2	-2.8
A-03-02 26DDB	949.0	879.9	-69.1
A-03-02 26CCA	945.0	871.9	-73.1
A-03-02 27DBB	942.0	875.6	-66.4
B-03-02 26CDD	777.0	761.6	-15.4
A-03-03 30CBC	958.0	900.5	-57.5
A-03-02 25CAC	955.0	887.4	-67.6
A-03-03 30CAC1	962.0	915.6	-46.4
A-03-02 25DBC1	956.0	887.5	-68.5
A-03-02 30DAD	937.0	904.3	-32.7
B-03-01 27CAA	707.0	775.8	68.8
B-03-01 26CBB2	704.0	792.9	88.9
A-03-01 26ADD	906.0	909.9	3.9
B-03-01 29BCC	720.0	747.7	27.7
A-03-02 25BDA	952.0	879.5	-72.5
A-03-02 26AAD	950.0	868.1	-81.9
A-03-02 27BAD	931.0	874.8	-56.2
B-03-01 27ABC2	710.0	772.3	62.3
A-03-02 25BAB	946.0	871.7	-74.3
A-03-02 29BBA	919.0	895.3	-23.7
A-03-02 26BAA2	938.0	864.1	-73.9
A-03-02 27BBB	935.0	877.8	-57.2
B-03-01 25BBB3	796.0	824.0	28.0
A-03-01 30BAA	826.0	839.3	13.3
B-03-01 26ABB	746.0	808.6	62.6
B-03-01 26BAB	707.0	801.4	94.4
A-03-01 25ABB	856.0	906.1	50.1
B-03-01 27ABB2	705.0	771.3	66.3
A-03-02 30BAA	924.0	903.0	-21.0
B-03-01 27BBB	788.0	764.4	-23.6
B-03-02 25BAA	746.0	754.2	8.2
B-03-02 26BAA	772.0	765.7	-6.3
A-03-01 22DDA3	913.0	902.8	-10.2
A-03-01 21CBB	878.0	867.7	-10.3
A-03-02 22DBB	917.0	870.4	-46.6
A-03-01 24CBB	891.0	900.8	9.8
A-03-02 23BCC	924.0	866.0	-58.0
B-03-01 19CBB	776.0	753.6	-22.4
A-03-01 19ACB	820.0	833.8	13.8
A-03-01 21ADA	885.0	884.9	-0.1
A-03-02 19AAD2	916.0	892.5	-23.5
B-03-01 23BBC	752.0	788.9	36.9
A-03-02 20AAA2	922.0	884.5	-37.5
A-03-02 24BAB2	885.0	858.9	-26.1
B-03-01 24BBB3	781.0	816.0	35.0
A-03-02 22BAA	920.0	870.4	-49.6
A-03-01 14DDD	911.0	901.5	-9.5
B-03-01 20BBB1	771.0	748.8	-22.2
A-03-02 15DDD	902.0	865.7	-36.3
A-03-02 17DCB	912.0	886.8	-25.2
A-03-01 16DAA	813.0	873.1	60.1
A-03-02 16DAA	913.0	872.5	-40.5
A-03-02 14CAB	902.0	861.3	-40.7
B-03-01 15CBB3	738.0	773.4	35.4
A-03-02 15ACD	885.0	866.7	-18.3
B-03-01 16DAB	752.0	747.7	-4.3
B-03-01 17DBB2	736.0	750.3	14.3
A-03-02 17BCC	856.0	885.8	29.8
B-03-02 14BCB2	819.0	778.5	-40.5
B-03-01 13BAA2	767.0	824.4	57.4
A-03-01 17ABB2	835.0	837.2	2.2
B-03-01 15BBB3	754.0	761.7	7.7
A-03-01 12CDB	832.0	878.5	46.5
A-03-01 11DDA	892.0	882.8	-9.2
B-03-01 08CBC	800.0	762.2	-37.8
B-03-01 12CBB1	735.0	817.1	82.1
A-03-02 09DAA	853.0	861.0	8.0
A-03-02 09DBB	854.0	866.6	12.6
A-03-02 10DBA	858.0	859.3	1.3
A-03-02 08DAB	887.0	872.8	-14.2
A-03-02 11BDC	860.0	861.0	1.0
B-03-01 08ACC	782.0	763.4	-18.6
B-03-02 10BDC	851.0	812.4	-38.6
B-03-01 12BBB2	773.0	819.1	46.1
B-03-01 08ABB2	787.0	782.9	-4.1
B-03-01 11BBB	771.0	798.3	27.3
A-03-02 08BBA2	863.0	871.0	8.0
A-03-01 04DDD1	794.0	843.4	49.4
A-03-02 03DDD	850.0	857.7	7.7
A-03-02 04CCD	866.0	862.3	-3.7
B-03-01 08ABB1	865.0	774.7	-90.3
B-03-02 11BAA	838.0	801.6	-36.4
A-03-01 06DAD	787.0	827.2	40.2
B-03-01 02DAD	766.0	818.6	52.6
A-03-01 04DBB	803.0	831.4	28.4
A-03-01 02BCC	827.0	852.4	25.4
B-03-02 02CBC	849.0	818.2	-30.8
A-03-02 06DAA	851.0	869.3	18.3
A-03-01 01BBA	828.0	851.7	23.7
A-03-01 03ABA2	816.0	843.2	27.2
A-03-02 04BAA	847.0	863.3	16.3
A-03-02 03AAB	840.0	860.8	20.8
A-03-01 05ABB2	788.0	821.3	33.3
A-03-02 01ABB	857.0	878.7	21.7
B-03-01 03BBB	758.0	819.0	61.0
B-03-01 06BAA	808.0	805.9	-2.1
B-03-02 01BBB	833.0	820.8	-12.2
B-03-02 03BAA	876.0	840.3	-35.7

APPENDIX TABLE C-3

REFINED MODEL UNWEIGHTED CALIBRATION RESIDUALS - ENTIRE MODEL DOMAIN

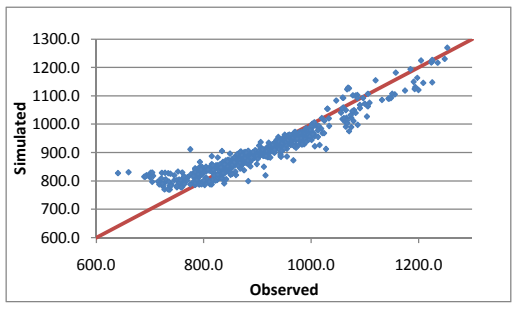
A-01-04 30BAB	1077.0	1083.3	6.3
A-01-04 30BDD	1080.0	1086.1	6.1
A-01-04 19ACC	1066.0	1082.8	16.8
A-01-04 18DAD	1081.0	1088.8	7.8
A-02-04 30ADD	1202.0	1135.2	-66.8

Mean Error	*2.38*
Abs Mean	*20.47*
RMSE	*28.66*



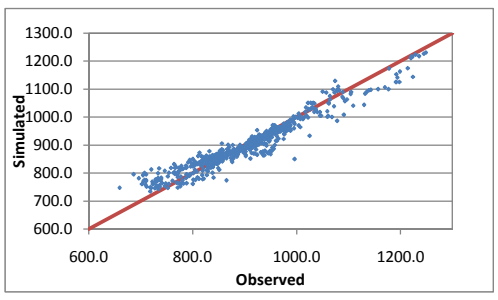
B-03-02 10BBA	849.0	826.8	-22.2
B-03-02 12AAA	810.0	797.5	-12.5
B-03-02 12BAA	800.0	801.7	1.7
B-03-02 11BAA	826.0	812.2	-13.8
A-03-01 04DBB	798.0	829.3	31.3
B-03-02 02CBC	853.0	824.6	-28.4
A-03-02 06DAA	863.0	894.6	31.6
B-03-01 02ACC	776.0	823.5	47.5
A-03-01 02BBB	792.0	839.4	47.4
A-03-01 04BAA3	788.0	824.4	36.4
A-03-01 05BBB2	782.0	810.9	28.9
A-03-02 03AAB	869.0	903.4	34.4
A-03-01 05ABB2	781.0	817.6	36.6
A-03-01 04BAA2	790.0	824.6	34.6
A-03-02 01ABB	903.0	924.5	21.5
B-03-01 05ABB	826.0	822.2	-3.8
B-03-01 06BAA	797.0	822.2	25.2
B-03-02 01BBB	728.0	828.5	100.5
B-03-02 02BAA	859.0	832.3	-26.7
B-03-02 03BAA	868.0	843.7	-24.3
B-04-02 35CCC	829.0	835.8	6.8
B-04-01 34CBB	784.0	831.9	47.9
A-04-02 33DBB2	849.0	896.0	47.0
A-04-02 34BDD	868.0	901.9	33.9
B-04-01 34DBB	793.0	834.6	41.6
B-04-02 34DBA	845.0	848.8	3.8
B-04-01 34ACB	799.0	835.5	36.5
B-04-01 32BBC	798.0	829.5	31.5
A-04-02 35AAB	883.0	905.9	22.9
A-04-01 32BAB	787.0	803.7	16.7
A-04-01 32ABB	833.0	809.0	-24.0
B-04-02 36BAA	818.0	838.9	20.9
B-04-02 34BBA	967.0	872.7	-94.3
B-04-01 30DCD	802.0	833.3	31.3
B-04-02 26DDD	832.0	844.1	12.1
A-04-01 30CCB	835.0	849.7	14.7
B-04-02 27DCD	867.0	863.2	-3.8
B-04-02 26DCB	831.0	849.2	18.2
A-04-01 30BCD	836.0	827.1	-8.9
A-04-01 30BCC	844.0	853.5	9.5
A-04-02 26CBA	874.0	894.0	20.0
B-04-01 27CBB	808.0	839.2	31.2
B-04-01 29ADC	804.0	839.3	35.3
A-04-01 30AAA1	792.0	847.6	55.6
A-04-01 30AAB2	797.0	849.3	52.3
A-04-01 29BBA	804.0	849.9	45.9
A-04-01 21CDD	791.0	845.9	54.9
B-04-01 28BAA	808.0	840.3	32.3
B-04-01 30ABB	912.0	850.0	-62.0
B-04-02 25BAA	830.0	858.2	28.2
B-04-02 26ABA	843.0	869.0	26.0
B-04-01 23CAB	844.0	852.0	8.0
B-04-03 19DBA	1226.0	1221.0	-5.0
A-04-01 22ADB	795.0	840.6	45.6
B-04-01 19BDC	839.0	858.8	19.8
B-04-02 24BCD	846.0	873.4	27.4
A-04-01 22AAA	817.0	854.9	37.9
A-04-02 22AAB	879.0	899.6	20.6
B-04-01 23BBB	864.0	853.7	-10.3
B-04-01 22ABB	887.0	851.2	-35.8
B-04-01 21BAA	832.0	848.1	16.1
B-04-01 19BBA	844.0	868.6	24.6
B-04-02 14CCA	1016.0	926.6	-89.4
A-04-01 18DAA	889.0	882.2	-6.8
B-04-03 15DAC	1198.0	1163.0	-35.0
B-04-02 16AAD	1087.0	997.7	-89.3
A-04-02 14BBB	906.0	937.1	31.1
B-04-01 18BAA	871.0	890.8	19.8
B-04-03 14ABA	1191.0	1149.3	-41.7
A-04-01 08DBD	945.0	905.2	-39.8
A-04-02 09CAD	909.0	911.4	2.4
A-04-03 07BCD1	1091.0	1067.8	-23.2
A-04-02 11ADB	1067.0	1002.7	-64.3
A-04-01 10ACA	955.0	886.3	-68.7
A-04-02 12ACB	1091.0	1056.2	-34.8
B-04-02 11BDB	1071.0	975.0	-96.0
B-04-02 10BCA	1104.0	1027.0	-77.0
A-04-01 06DCD1	1013.0	955.4	-57.6
B-04-02 05DBB	1151.0	1106.9	-44.1
B-04-03 04BDB	1236.0	1216.7	-19.3
A-05-01 31DAD	1077.0	1046.3	-30.7
B-05-03 33BCB	1249.0	1230.2	-18.8
B-05-02 35BAA	1100.0	1072.4	-27.6
B-05-03 22ADD	1224.0	1217.1	-6.9
B-05-02 24BAD	1067.0	1123.0	56.0
B-05-02 24BAB	1071.0	1126.2	55.2
B-05-02 13CDB	1069.0	1128.3	59.3
B-05-02 15CCB	1120.0	1154.6	34.6
B-05-02 17ABD	1158.0	1181.9	23.9
B-05-03 15AAA	1226.0	1226.3	0.3
B-05-02 08CCB	1185.0	1193.4	8.4
B-06-03 36DDD	1205.0	1224.3	19.3
B-06-03 33DCB	1254.0	1269.8	15.8

Mean Error	*-0.17*
Abs Mean	*23.77*
RMSE	*33.77*



A-04-02 32DDA	840.0	861.3	21.3
A-04-02 32DDA	840.0	861.3	21.3
A-04-02 32DDA	846.0	862.2	16.2
A-04-02 32CAA	831.0	857.8	26.8
B-04-01 34CBB	778.0	826.1	48.1
A-04-02 33DBB2	824.0	856.9	32.9
A-04-02 34BDD	839.0	860.6	21.6
B-04-01 33CBB	800.0	825.0	25.0
B-04-02 34DBA	875.0	846.2	-28.8
A-04-01 35BBC	811.0	837.6	26.6
B-04-02 36BCB	846.0	836.3	-9.7
A-04-02 32BAA2	825.0	848.8	23.8
A-04-02 27DDD	837.0	854.2	17.2
A-04-01 34ABA1	798.0	834.6	36.6
B-04-02 27DCD	860.0	861.0	1.0
A-04-02 29BCD	840.0	843.9	3.9
B-04-02 26DBB	865.0	860.3	-4.7
B-04-01 30BCD	996.0	850.7	-145.3
A-04-01 27BAB1	791.0	838.8	47.8
A-04-01 27AAA	804.0	835.0	31.0
A-04-01 28AAB	794.0	847.1	53.1
B-04-01 29ABB	820.0	851.4	31.4
B-04-01 30ABB	828.0	856.7	28.7
B-04-02 25BAA	842.0	862.9	20.9
B-04-01 24DBB	870.0	868.2	-1.8
B-04-01 23DBA	861.0	864.7	3.7
B-04-03 19DBA	1223.0	1215.2	-7.8
B-04-02 24BCD	852.0	879.8	27.8
A-04-01 23ADB	754.0	801.8	47.8
B-04-01 20BCB	838.0	864.5	26.5
A-04-01 22AAA	804.0	842.4	38.4
B-04-01 19BBA	902.0	877.1	-24.9
A-04-01 14DAD	764.0	832.5	68.5
B-04-02 14CCA	1025.0	933.6	-91.4
A-04-01 13CBB	849.0	836.3	-12.7
B-04-01 18CBD	866.0	885.6	19.6
A-04-01 18DAA	900.0	892.3	-7.7
A-04-01 15BDD	810.0	861.2	51.2
B-04-03 15DAC	1199.0	1162.7	-36.3
B-04-02 16AAD	1091.0	1008.6	-82.4
A-04-02 16ABB	868.0	901.3	33.3
A-04-02 14BBB	920.0	926.7	6.7
B-04-01 14BBB	910.0	883.6	-26.4
B-04-01 18BAA	877.0	900.4	23.4
B-04-03 14ABA	1192.0	1152.7	-39.3
A-04-01 08DBD	960.0	915.9	-44.1
A-04-02 09CAD	902.0	905.2	3.2
A-04-03 07BCD1	1088.0	1072.2	-15.8
A-04-02 11ADB	1068.0	1000.7	-67.3
A-04-02 12ACB	1093.0	1057.3	-35.7
B-04-02 11BDB	1078.0	986.8	-91.2
B-04-02 10BCA	1109.0	1041.0	-68.0
A-04-03 06BCD	1214.0	1174.4	-39.6
A-04-01 05ACD	1059.0	1020.9	-38.1
A-04-01 04BBB1	1130.0	1043.9	-86.1
B-04-03 04BDB	1236.0	1217.4	-18.6
A-05-01 33BCC	1177.0	1099.8	-77.2
B-05-03 33BCB	1249.0	1230.4	-18.6
B-05-02 35BAA	1104.0	1082.9	-21.1
B-05-02 26DDD	1064.0	1075.3	11.3
B-05-02 30ADD	1178.0	1173.6	-4.4
B-05-03 21DDA	1245.0	1226.4	-18.6
B-05-03 22ADD	1221.0	1216.3	-4.7
B-05-02 24BAB	1074.0	1129.4	55.4
B-05-03 23ABB	1220.0	1210.3	-9.7
B-05-03 15AAA	1229.0	1223.1	-5.9
B-06-02 30ADB	1316.0	1223.3	-92.7

Mean Error	*-3.08*
Abs Mean	*18.75*
RMSE	*27.34*



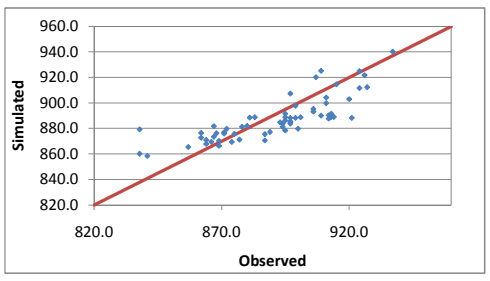
APPENDIX TABLE C-4

REFINED MODEL UNWEIGHTED CALIBRATION RESIDUALS - AVONDALE STUDY AREA

2002/2003 Calibration Data (Avondale Study Area)

Local ID	Measured Elevations (ft-amsl)	Simulated Elevations (ft-amsl)	Unweighted Residual (feet)
B-01-01 28CDC	895.0	891.4	-3.6
A-01-01 28CAC	937.0	940.0	3.0
B-01-01 27DAB2	897.0	907.2	10.2
A-01-01 30AAC2	909.0	925.0	16.0
A-01-01 30AAC1	924.0	924.9	0.9
B-01-01 25BAA	915.0	914.4	-0.6
A-01-01 30BAA1	907.0	920.0	13.0
A-01-01 19DCD1	926.0	921.6	-4.4
B-01-01 28AAB	897.0	888.3	-8.7
B-01-01 22ACD	906.0	895.2	-10.8
B-01-01 24ABB	911.0	904.1	-6.9
A-01-01 19ABB	924.0	911.4	-12.6
B-01-01 15CCB	899.0	888.1	-10.9
B-01-01 13DBC	920.0	902.8	-17.2
A-01-01 17DAA	927.0	912.3	-14.7
B-01-01 15BAD	895.0	888.6	-6.4
A-01-01 07CCD	911.0	899.6	-11.4
B-01-01 11CCB1	909.0	890.0	-19.0
B-01-01 10DDB	883.0	888.7	5.7
B-01-01 10CBD	897.0	884.9	-12.1
B-01-01 10BCC	897.0	883.6	-13.4
B-01-01 10BDA	893.0	884.7	-8.3
B-01-01 10BDB	894.0	883.7	-10.3
B-01-01 11AAA	912.0	890.1	-21.9
A-01-01 09BBB2	899.0	897.8	-1.2
B-01-01 12AAA1	906.0	893.1	-12.9
B-01-01 12BAA2	913.0	891.4	-21.6
B-01-01 11BAB	912.0	887.5	-24.5
B-01-01 10AAA2	897.0	885.5	-11.5
A-01-01 06CBB1	901.0	888.6	-12.4
B-01-01 01CAA	913.0	889.0	-24.0
B-01-01 03DAB	872.0	879.6	7.6
B-01-01 03DBA	900.0	879.6	-20.4
B-01-01 02AAD2	921.0	888.1	-32.9
B-01-01 04ABA2	838.0	879.1	41.1
B-01-01 02BBB	894.0	881.1	-12.9
A-02-01 33CCC	881.0	888.4	7.4
A-02-01 32DDA	895.0	886.2	-8.8
B-02-01 34DDA	889.0	877.2	-11.8
B-02-01 36CBA2	914.0	888.9	-25.1
B-02-01 35DAA	895.0	878.3	-16.7
A-02-01 32DAB2	880.0	882.0	2.0
B-02-01 34CAA2	887.0	875.5	-11.5
B-02-01 36BBC	875.0	875.7	0.7
B-02-01 36BAA	867.0	881.7	14.7
A-02-01 30DDD2	871.0	876.8	5.8
A-02-01 29DDD2	878.0	881.2	3.2
B-02-01 27CBC	887.0	870.5	-16.5
B-02-01 26CBC2	874.0	869.3	-4.7
A-02-01 30CBB	864.0	870.8	6.8
A-02-01 30DAA2	862.0	872.7	10.7
A-02-01 30CAA2	864.0	867.7	3.7
A-02-01 29CAA2	868.0	876.1	8.1
B-02-01 25ADC	862.0	876.3	14.3
B-02-01 26ACA	857.0	865.4	8.4
B-02-01 25BBB	838.0	860.0	22.0
A-02-01 20DDD2	871.0	875.8	4.8
A-02-01 20CCC2	866.0	869.4	3.4
A-02-01 20DCC	867.0	873.4	6.4
B-02-01 23DDD	841.0	858.4	17.4
A-02-01 20CAC	869.0	870.0	1.0
A-02-01 20DAA	877.0	871.1	-5.9
A-02-01 20BCC2	869.0	866.2	-2.8

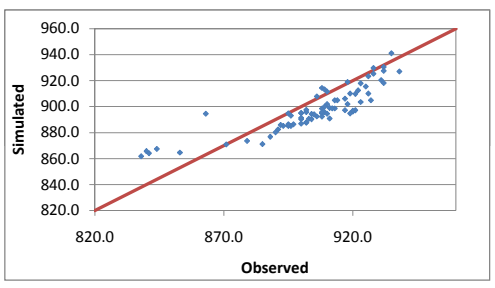
ME	*-3.70*
AME	*11.26*
RMSE	*13.77*



1997/1998 Calibration Data (Avondale Study Area)

Local ID	Measured Elevations (ft-amsl)	Simulated Elevations (ft-amsl)	Unweighted Residual (feet)
B-01-01 28CDC	895.0	894.7	-0.3
B-01-01 27DAB2	910.0	911.6	1.6
B-01-01 25ADA	926.0	923.4	-2.6
A-01-01 28BCB	935.0	941.0	6.0
A-01-01 30AAC2	932.0	930.5	-1.5
A-01-01 30AAC1	928.0	929.6	1.6
B-01-01 25BAA	923.0	917.9	-5.1
A-01-01 30BAA1	928.0	925.3	-2.7
A-01-01 19DCD1	932.0	927.5	-4.5
B-01-01 28ABA	900.0	895.1	-4.9
B-01-01 28AAB	902.0	895.8	-6.2
B-01-01 22ACD	910.0	901.9	-8.1
B-01-01 24ABB	922.0	912.6	-9.4
A-01-01 19ABB	931.0	920.3	-10.7
B-01-01 15DCA	908.0	898.5	-9.5
B-01-01 15CCB	904.0	894.3	-9.7
B-01-01 13DBC	926.0	910.2	-15.8
A-01-01 17DAA	938.0	927.1	-10.9
B-01-01 15BAD	900.0	895.2	-4.8
A-01-01 17BBB	932.0	918.2	-13.8
B-01-01 10CCD	896.0	893.0	-3.0
A-01-01 07CCD	921.0	909.9	-11.1
B-01-01 10DCC	863.0	894.6	31.6
B-01-01 11CCB1	920.0	896.3	-23.7
B-01-01 10DDB	908.0	894.9	-13.1
B-01-01 09DDB	900.0	890.4	-9.6
B-01-01 10CBB	903.0	890.7	-12.3
A-01-01 09BAC	918.0	919.0	1.0
B-01-01 10BDA	900.0	891.5	-8.5
B-01-01 11AAA	921.0	897.2	-23.8
A-01-01 09BBB2	925.0	915.5	-9.5
B-01-01 12AAA1	918.0	902.0	-16.0
B-01-01 12BAA2	911.0	898.9	-12.1
B-01-01 11AAB	920.0	896.9	-23.1
B-01-01 11BAB	919.0	894.8	-24.2
B-01-01 10AAA2	906.0	892.5	-13.5
B-01-01 03DAC	904.0	890.4	-13.6
A-01-01 04CAB	908.0	914.4	6.4
A-01-01 06CBB1	913.0	898.6	-14.4
B-01-01 01CAA	917.0	897.3	-19.7
B-01-01 01BAC	909.0	895.8	-13.2
A-01-01 04BAC	909.0	913.2	4.2
B-01-01 04ABA2	893.0	885.2	-7.8
B-01-01 03BAA	897.0	886.4	-10.6
B-01-01 02BBB	902.0	887.8	-14.2
B-02-01 36CDD	910.0	894.6	-15.4
A-02-01 33CCC	919.0	910.1	-8.9
A-02-01 32DDA	906.0	907.9	1.9
B-02-01 34DDA	896.0	885.2	-10.8
B-02-01 36CBB	902.0	888.1	-13.9
A-02-01 32DAB2	914.0	905.0	-9.0
B-02-01 34CAA2	890.0	880.3	-9.7
B-02-01 36BBC	895.0	885.1	-9.9
A-02-01 32AAC	913.0	904.8	-8.2
B-02-01 36BAA	892.0	885.9	-6.1
A-02-01 30DDD2	902.0	897.5	-4.5
A-02-01 29DDD2	917.0	906.1	-10.9
B-02-01 27DCC	888.0	876.9	-11.1
B-02-01 27CBC	885.0	871.3	-13.7
B-02-01 26CBC2	879.0	873.7	-5.3
A-02-01 30CBB	895.0	886.4	-8.6
A-02-01 30DAA2	905.0	894.1	-10.9
A-02-01 30CAA2	900.0	887.0	-13.0
A-02-01 29CAA2	909.0	900.1	-8.9
B-02-01 25ADC	891.0	882.4	-8.6
B-02-01 26ACA	871.0	871.0	0.0
B-02-01 25BBB	844.0	867.6	23.6
B-02-01 26AAA	853.0	864.7	11.7
A-02-01 20DDD2	923.0	903.6	-19.4
A-02-01 20CCC2	908.0	892.3	-15.7
B-02-01 23DCC	840.0	865.9	25.9
A-02-01 20DCC	912.0	898.7	-13.3
B-02-01 23DCB	841.0	864.2	23.2
A-02-01 20CAC	908.0	895.7	-12.3
A-02-01 20DAA	927.0	904.9	-22.1
B-02-01 23DBB	838.0	862.0	24.0
A-02-01 20BCC2	911.0	890.9	-20.1

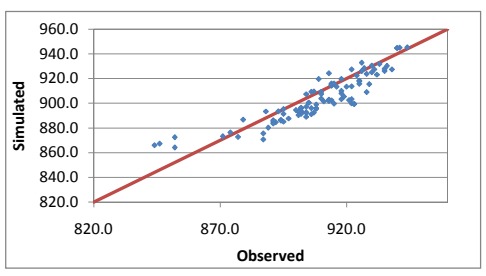
ME	*-7.08*
AME	*11.31*
RMSE	*13.22*



1991/1992 Calibration Data (Avondale Study Area)

Local ID	Measured Elevations (ft-amsl)	Simulated Elevations (ft-amsl)	Unweighted Residual (feet)
B-01-01 34AAA	914.0	914.3	0.3
A-01-01 29DCD	941.0	945.1	4.1
A-01-01 28CAC	944.0	945.2	1.2
A-01-01 29DAA2	940.0	944.7	4.7
A-01-01 29DAA1	940.0	944.9	4.9
B-01-01 27DAB1	910.0	909.3	-0.7
B-01-01 27DAB2	906.0	909.3	3.3
B-01-01 25ADA	928.0	923.8	-4.2
A-01-01 30AAC2	926.0	932.9	6.9
A-01-01 30AAC1	933.0	931.8	-1.2
A-01-01 30BAA2	931.0	927.3	-3.7
B-01-01 25BAA	925.0	918.4	-6.6
A-01-01 30BAA1	922.0	927.4	5.4
A-01-01 19CCD	930.0	925.1	-4.9
A-01-01 19DCD1	936.0	930.4	-5.6
B-01-01 28ABA	902.0	895.9	-6.1
A-01-01 19CCC	932.0	923.2	-8.8
B-01-01 28AAB	902.0	896.5	-5.5
B-01-01 22ACD	913.0	902.9	-10.1
A-01-01 19ACB2	913.0	924.3	11.3
A-01-01 19ABB	935.0	926.1	-8.9
B-01-01 15CCB	906.0	896.1	-9.9
B-01-01 13DBC	929.0	915.5	-13.5
B-01-01 16DBD	901.0	893.3	-7.7
A-01-01 18ACB	924.0	922.5	-1.5
B-01-01 16ADB	904.0	892.7	-11.3
B-01-01 15BAD	904.0	897.2	-6.8
B-01-01 16AAC	902.0	892.5	-9.5
A-01-01 17BBB	935.0	928.1	-6.9
B-01-01 16AAB	907.0	892.5	-14.5
B-01-01 10CCD	900.0	894.5	-5.5
A-01-01 07CCD	925.0	917.9	-7.1
B-01-01 11CCB2	922.0	899.8	-22.2
B-01-01 11CCB1	923.0	899.5	-23.5
B-01-01 09DDB	906.0	891.2	-14.8
B-01-01 10CBD	893.0	893.4	0.4
A-01-01 08CAB	938.0	927.6	-10.4
B-01-01 10CBB	904.0	892.2	-11.8
B-01-01 10ACD	908.0	896.0	-12.0
A-01-01 09BAC	930.0	930.6	0.6
B-01-01 10BDA	902.0	893.6	-8.4
A-01-01 08BAA	926.0	926.2	0.2
B-01-01 11AAA	922.0	903.4	-18.6
A-01-01 09BBB2	927.0	928.5	1.5
B-01-01 12BAA2	918.0	908.1	-9.9
B-01-01 11AAB	921.0	902.5	-18.5
A-01-01 06CDD	925.0	915.8	-9.2
B-01-01 11BAB	923.0	899.3	-23.7
B-01-01 09AAB	904.0	888.9	-15.1
B-01-01 10AAA2	908.0	895.6	-12.4
B-01-01 03DAC	901.0	893.1	-7.9
A-01-01 06CBB2	918.0	910.2	-7.8
B-01-01 01CAB	918.0	903.4	-14.6
A-01-01 06CBB1	928.0	909.0	-19.0
B-01-01 01CAA	919.0	905.4	-13.6
A-01-01 06DAA	918.0	919.8	1.8
B-01-01 02DAA	915.0	899.7	-15.3
B-01-01 04CAA	894.0	886.0	-8.0
B-01-01 01BDA	913.0	901.9	-11.1
B-01-01 02BCB	902.0	891.3	-10.7
B-01-01 01BAC	913.0	902.8	-10.2
B-01-01 01BAD	914.0	902.4	-11.6
B-01-01 04ABA2	892.0	884.7	-7.3
B-01-01 04AAB	891.0	885.0	-6.0
B-01-01 03BAA	897.0	887.6	-9.4
B-01-01 02BBB	901.0	890.4	-10.6
B-02-01 36CDD	911.0	901.4	-9.6
A-02-01 32DDA	909.0	919.7	10.7
B-02-01 34DDA	894.0	886.6	-7.4
A-02-01 31DAA	916.0	913.4	-2.6
A-02-01 32DAB2	914.0	914.8	0.8
B-02-01 34CAA2	889.0	880.4	-8.6
B-02-01 36ACD	905.0	900.4	-4.6
A-02-01 32ACA	914.0	915.9	1.9
A-02-01 32AAC	914.0	914.9	0.9
B-02-01 35ABD	895.0	885.1	-9.9
B-02-01 36BAA	895.0	891.4	-3.6
B-02-01 36BBA3	891.0	886.1	-4.9
B-02-01 35AAB	891.0	883.7	-7.3
A-02-01 30DDD2	904.0	907.4	3.4
A-02-01 29DDD2	915.0	916.1	1.1
B-02-01 27DCC	887.0	875.5	-11.5
B-02-01 27CBC	887.0	870.7	-16.3
B-02-01 26CBC2	877.0	872.7	-4.3
A-02-01 30CBB	888.0	893.4	5.4
A-02-01 30CAA2	895.0	895.3	0.3
A-02-01 29CAA2	907.0	909.6	2.6
B-02-01 25BCB	874.0	876.3	2.3
B-02-01 26ACA	871.0	873.3	2.3
B-02-01 25ACA	879.0	886.7	7.7
B-02-01 25BBB	852.0	872.4	20.4
A-02-01 20DDD2	920.0	913.5	-6.5
A-02-01 20CCC2	905.0	900.5	-4.5
A-02-01 20DCC	910.0	907.5	-2.5
B-02-01 23DDD	846.0	867.4	21.4
B-02-01 23DCB	844.0	866.0	22.0
A-02-01 20CAC	910.0	903.8	-6.2
A-02-01 20DAA	922.0	913.8	-8.2
B-02-01 23DBB	852.0	864.3	12.3
A-02-01 20BCC2	908.0	898.9	-9.1

ME	*-4.99*
AME	*8.24*
RMSE	*10.02*



THIS PAGE INTENTIONALLY LEFT BLANK

D: Assumed Annual Pumping for Water Supply Alternatives

THIS PAGE INTENTIONALLY LEFT BLANK

APPENDIX FIGURE D-1

ALTERNATIVE 1 ASSUMED ANNUAL PUMPING

Production (GPM)

Date	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026
Stress Period	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44
Total Pumping (mgd)	10.4	12.1	12.9	11.9	12.9	12.9	13.4	13.9	14.4	14.9	15.2	16.1	16.9	17.6	18.4	19.1	19.7	20.3	21.0	21.6	22.2	22.8
1	3	5	1	0	2	2	0	0	0	0	0	0	0	0	0	423	457	492	532	567	602	637
5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
6	523	555	397	409	420	420	420	420	420	420	420	420	420	420	420	420	420	420	420	420	420	420
7	500	559	367	184	365	365	365	365	365	365	365	365	365	365	365	365	365	365	365	365	365	365
8A	517	497	482	505	440	440	440	440	440	440	0	0	0	0	0	423	457	492	532	567	602	637
10	1303	1536	1100	1127	1167	1167	1167	1167	1167	1167	1167	1167	1167	1167	1167	1167	1167	1167	1167	1167	1167	1167
11	486	785	1058	767	727	727	727	727	727	727	727	727	727	727	727	727	727	727	727	727	727	727
12	1316	910	1229	1252	1070	1070	1070	1070	1070	1070	1070	1070	1070	1070	1070	1070	1070	1070	1070	1070	1070	1070
14	140	0	0	0	0	0	0	0	0	0	0	0	0	0	0	423	457	492	532	567	602	637
15	201	218	342	309	251	251	251	251	251	251	251	251	251	251	251	251	251	251	251	251	251	251
16	964	1267	1393	1302	1132	1132	1132	1132	1132	1132	1132	1132	1132	1132	1132	1132	1132	1132	1132	1132	1132	1132
16B	86	110	122	112	98	98	138	138	138	138	138	138	138	138	138	138	138	138	138	138	138	138
17	0	0	205	303	144	144	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
18	526	1354	1363	1257	963	963	963	963	963	963	963	963	963	963	963	963	963	963	963	963	963	963
19	652	619	893	762	687	687	687	687	687	687	687	687	687	687	687	687	687	687	687	687	687	687
20	0	0	0	0	208	208	348	347	278	248	337	431	506	575	655	423	457	492	532	567	602	637
21	0	0	0	0	0	0	348	347	278	248	337	431	506	575	655	423	457	492	532	567	602	637
22	0	0	0	0	0	0	0	347	278	248	337	431	506	575	655	423	457	492	532	567	602	637
23	0	0	0	0	1275	1275	1275	1275	1275	1275	1275	1275	1275	1275	1275	1275	1275	1275	1275	1275	1275	1275
24	0	0	0	0	0	0	0	0	278	248	337	431	506	575	655	423	457	492	532	567	602	637
25	0	0	0	0	0	0	0	0	278	248	337	431	506	575	655	423	457	492	532	567	602	637
26	0	0	0	0	0	0	0	0	0	248	337	431	506	575	655	423	457	492	532	567	602	637
28	0	0	0	0	0	0	0	0	0	248	337	431	506	575	655	423	457	492	532	567	602	637
30	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	423	457	492	532	567	602	637
31	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	423	457	492	532	567	602	637
32	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
33	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
34	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
35	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
36	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
37	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
39	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
40	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
45	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

APPENDIX FIGURE D-1

ALTERNATIVE 1 ASSUMED ANNUAL PUMPING

2027	2028	2029	2030	2031	2032	2033	2034	2035	2036	2037	2038	2039	2040	2041	2042	2043	2044	2045	2046	2047	2048	2049	2050
45	46	47	48	49	50	51	52	53	54	55	56	57	58	59	60	61	62	63	64	65	66	67	68
23.4	24.1	24.7	25.3	25.4	25.4	25.5	25.5	25.6	25.6	25.7	25.7	25.8	25.9	25.9	26.0	26.0	26.1	26.1	26.2	26.2	26.3	26.4	26.4
671	671	671	469	472	472	476	476	479	479	483	483	486	490	490	493	493	497	497	500	500	504	483	483
0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	2	3	4	5	6	7	8	0	0
420	420	420	420	420	420	420	420	420	420	420	420	420	420	420	420	420	420	420	420	420	420	420	420
365	365	365	365	365	365	365	365	365	365	365	365	365	365	365	365	365	365	365	365	365	365	365	365
671	713	751	469	472	472	476	476	479	479	483	483	486	490	490	493	493	497	497	500	500	504	483	483
1167	1167	1167	1167	1167	1167	1167	1167	1167	1167	1167	1167	1167	1167	1167	1167	1167	1167	1167	1167	1167	1167	1167	1167
727	727	727	727	727	727	727	727	727	727	727	727	727	727	727	727	727	727	727	727	727	727	727	727
1070	1070	1070	1070	1070	1070	1070	1070	1070	1070	1070	1070	1070	1070	1070	1070	1070	1070	1070	1070	1070	1070	1070	1070
671	713	751	469	472	472	476	476	479	479	483	483	486	490	490	493	493	497	497	500	500	504	483	483
251	251	251	251	251	251	251	251	251	251	251	251	251	251	251	251	251	251	251	251	251	251	251	251
1132	1132	1132	1132	1132	1132	1132	1132	1132	1132	1132	1132	1132	1132	1132	1132	1132	1132	1132	1132	1132	1132	1132	1132
138	138	138	138	138	138	138	138	138	138	138	138	138	138	138	138	138	138	138	138	138	138	138	138
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
963	963	963	963	963	963	963	963	963	963	963	963	963	963	963	963	963	963	963	963	963	963	963	963
687	687	687	687	687	687	687	687	687	687	687	687	687	687	687	687	687	687	687	687	687	687	687	687
671	713	751	469	472	472	476	476	479	479	483	483	486	490	490	493	493	497	497	500	500	504	483	483
671	713	751	469	472	472	476	476	479	479	483	483	486	490	490	493	493	497	497	500	500	504	483	483
671	713	751	469	472	472	476	476	479	479	483	483	486	490	490	493	493	497	497	500	500	504	483	483
1275	1275	1275	1275	1275	1275	1275	1275	1275	1275	1275	1275	1275	1275	1275	1275	1275	1275	1275	1275	1275	1275	1275	1275
671	713	751	469	472	472	476	476	479	479	483	483	486	490	490	493	493	497	497	500	500	504	483	483
671	713	751	469	472	472	476	476	479	479	483	483	486	490	490	493	493	497	497	500	500	504	483	483
671	713	751	469	472	472	476	476	479	479	483	483	486	490	490	493	493	497	497	500	500	504	483	483
671	713	751	469	472	472	476	476	479	479	483	483	486	490	490	493	493	497	497	500	500	504	483	483
671	713	751	469	472	472	476	476	479	479	483	483	486	490	490	493	493	497	497	500	500	504	483	483
671	713	751	469	472	472	476	476	479	479	483	483	486	490	490	493	493	497	497	500	500	504	483	483
0	0	0	469	472	472	476	476	479	479	483	483	486	490	490	493	493	497	497	500	500	504	483	483
0	0	0	469	472	472	476	476	479	479	483	483	486	490	490	493	493	497	497	500	500	504	483	483
0	0	0	469	472	472	476	476	479	479	483	483	486	490	490	493	493	497	497	500	500	504	483	483
0	0	0	469	472	472	476	476	479	479	483	483	486	490	490	493	493	497	497	500	500	504	483	483
0	0	0	469	472	472	476	476	479	479	483	483	486	490	490	493	493	497	497	500	500	504	483	483
0	0	0	469	472	472	476	476	479	479	483	483	486	490	490	493	493	497	497	500	500	504	483	483
0	0	0	469	472	472	476	476	479	479	483	483	486	490	490	493	493	497	497	500	500	504	483	483
0	0	0	469	472	472	476	476	479	479	483	483	486	490	490	493	493	497	497	500	500	504	483	483
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	483	483

APPENDIX TABLE D-2

ALTERNATIVE 2 ASSUMED ANNUAL PUMPING

Production (GPM)

Date	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026
Stress Period	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44
Total Pumping (mgd)	10.4	12.1	12.9	11.9	12.9	12.9	13.4	13.9	14.4	14.9	15.2	16.1	16.9	17.6	18.4	19.1	19.7	20.3	21.0	21.6	22.2	22.8
1	3	5	1	0	2	2	0	0	0	0	0	0	0	0	0	423	457	492	532	567	602	637
5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
6	523	555	397	409	420	420	420	420	420	420	420	420	420	420	420	420	420	420	420	420	420	420
7	500	559	367	184	365	365	365	365	365	365	365	365	365	365	365	365	365	365	365	365	365	365
8A	517	497	482	505	440	440	440	440	440	440	0	0	0	0	0	423	457	492	532	567	602	637
10	1303	1536	1100	1127	1167	1167	1167	1167	1167	1167	1167	1167	1167	1167	1167	1167	1167	1167	1167	1167	1167	1167
11	486	785	1058	767	727	727	727	727	727	727	727	727	727	727	727	727	727	727	727	727	727	727
12	1316	910	1229	1252	1070	1070	1070	1070	1070	1070	1070	1070	1070	1070	1070	1070	1070	1070	1070	1070	1070	1070
14	140	0	0	0	0	0	0	0	0	0	0	0	0	0	0	423	457	492	532	567	602	637
15	201	218	342	309	251	251	251	251	251	251	251	251	251	251	251	251	251	251	251	251	251	251
16	964	1267	1393	1302	1132	1132	1132	1132	1132	1132	1132	1132	1132	1132	1132	1132	1132	1132	1132	1132	1132	1132
16B	86	110	122	112	98	98	138	138	138	138	138	138	138	138	138	138	138	138	138	138	138	138
17	0	0	205	303	144	144	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
18	526	1354	1363	1257	963	963	963	963	963	963	963	963	963	963	963	963	963	963	963	963	963	963
19	652	619	893	762	687	687	687	687	687	687	687	687	687	687	687	687	687	687	687	687	687	687
20	0	0	0	0	208	208	348	347	278	248	337	431	506	575	655	423	457	492	532	567	602	637
21	0	0	0	0	0	0	348	347	278	248	337	431	506	575	655	423	457	492	532	567	602	637
22	0	0	0	0	0	0	0	347	278	248	337	431	506	575	655	423	457	492	532	567	602	637
23	0	0	0	0	1275	1275	1275	1275	1275	1275	1275	1275	1275	1275	1275	1275	1275	1275	1275	1275	1275	1275
24	0	0	0	0	0	0	0	0	278	248	337	431	506	575	655	423	457	492	532	567	602	637
25	0	0	0	0	0	0	0	0	278	248	337	431	506	575	655	423	457	492	532	567	602	637
26	0	0	0	0	0	0	0	0	0	248	337	431	506	575	655	423	457	492	532	567	602	637
28	0	0	0	0	0	0	0	0	0	248	337	431	506	575	655	423	457	492	532	567	602	637
30	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	423	457	492	532	567	602	637
33	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	423	457	492	532	567	602	637
34	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
35	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
36	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
37	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
38	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
39	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
40	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
44	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
45	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

APPENDIX TABLE D-2

ALTERNATIVE 2 ASSUMED ANNUAL PUMPING

2027	2028	2029	2030	2031	2032	2033	2034	2035	2036	2037	2038	2039	2040	2041	2042	2043	2044	2045	2046	2047	2048	2049	2050
45	46	47	48	49	50	51	52	53	54	55	56	57	58	59	60	61	62	63	64	65	66	67	68
23.4	24.1	24.7	25.3	25.4	25.4	25.5	25.5	25.6	25.6	25.7	25.7	25.8	25.9	25.9	26.0	26.0	26.1	26.1	26.2	26.2	26.3	26.4	26.4
671	671	671	469	472	472	476	476	479	479	483	483	486	490	490	493	493	497	497	500	500	504	483	483
0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	2	3	4	5	6	7	8	0	0
420	420	420	420	420	420	420	420	420	420	420	420	420	420	420	420	420	420	420	420	420	420	420	420
365	365	365	365	365	365	365	365	365	365	365	365	365	365	365	365	365	365	365	365	365	365	365	365
671	713	751	469	472	472	476	476	479	479	483	483	486	490	490	493	493	497	497	500	500	504	483	483
1167	1167	1167	1167	1167	1167	1167	1167	1167	1167	1167	1167	1167	1167	1167	1167	1167	1167	1167	1167	1167	1167	1167	1167
727	727	727	727	727	727	727	727	727	727	727	727	727	727	727	727	727	727	727	727	727	727	727	727
1070	1070	1070	1070	1070	1070	1070	1070	1070	1070	1070	1070	1070	1070	1070	1070	1070	1070	1070	1070	1070	1070	1070	1070
671	713	751	469	472	472	476	476	479	479	483	483	486	490	490	493	493	497	497	500	500	504	483	483
251	251	251	251	251	251	251	251	251	251	251	251	251	251	251	251	251	251	251	251	251	251	251	251
1132	1132	1132	1132	1132	1132	1132	1132	1132	1132	1132	1132	1132	1132	1132	1132	1132	1132	1132	1132	1132	1132	1132	1132
138	138	138	138	138	138	138	138	138	138	138	138	138	138	138	138	138	138	138	138	138	138	138	138
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
963	963	963	963	963	963	963	963	963	963	963	963	963	963	963	963	963	963	963	963	963	963	963	963
687	687	687	687	687	687	687	687	687	687	687	687	687	687	687	687	687	687	687	687	687	687	687	687
671	713	751	469	472	472	476	476	479	479	483	483	486	490	490	493	493	497	497	500	500	504	483	483
671	713	751	469	472	472	476	476	479	479	483	483	486	490	490	493	493	497	497	500	500	504	483	483
671	713	751	469	472	472	476	476	479	479	483	483	486	490	490	493	493	497	497	500	500	504	483	483
1275	1275	1275	1275	1275	1275	1275	1275	1275	1275	1275	1275	1275	1275	1275	1275	1275	1275	1275	1275	1275	1275	1275	1275
671	713	751	469	472	472	476	476	479	479	483	483	486	490	490	493	493	497	497	500	500	504	483	483
671	713	751	469	472	472	476	476	479	479	483	483	486	490	490	493	493	497	497	500	500	504	483	483
671	713	751	469	472	472	476	476	479	479	483	483	486	490	490	493	493	497	497	500	500	504	483	483
671	713	751	469	472	472	476	476	479	479	483	483	486	490	490	493	493	497	497	500	500	504	483	483
671	713	751	469	472	472	476	476	479	479	483	483	486	490	490	493	493	497	497	500	500	504	483	483
671	713	751	469	472	472	476	476	479	479	483	483	486	490	490	493	493	497	497	500	500	504	483	483
0	0	0	469	472	472	476	476	479	479	483	483	486	490	490	493	493	497	497	500	500	504	483	483
0	0	0	469	472	472	476	476	479	479	483	483	486	490	490	493	493	497	497	500	500	504	483	483
0	0	0	469	472	472	476	476	479	479	483	483	486	490	490	493	493	497	497	500	500	504	483	483
0	0	0	469	472	472	476	476	479	479	483	483	486	490	490	493	493	497	497	500	500	504	483	483
0	0	0	469	472	472	476	476	479	479	483	483	486	490	490	493	493	497	497	500	500	504	483	483
0	0	0	469	472	472	476	476	479	479	483	483	486	490	490	493	493	497	497	500	500	504	483	483
0	0	0	469	472	472	476	476	479	479	483	483	486	490	490	493	493	497	497	500	500	504	483	483
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	483	483

APPENDIX TABLE D-3

ALTERNATIVE 3 ASSUMED ANNUAL PUMPING

Production (GPM)

Date	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026
Stress Period	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44
Total Pumping (mgd)	10.4	12.1	12.9	11.9	12.9	12.9	13.4	13.9	14.4	14.9	15.2	16.1	16.9	17.6	18.4	19.1	19.7	20.3	21.0	21.6	22.2	22.8
1	3	5	1	0	2	2	0	0	0	0	0	0	0	0	0	423	457	492	532	567	602	637
5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
6	523	555	397	409	420	420	420	420	420	420	420	420	420	420	420	420	420	420	420	420	420	420
7	500	559	367	184	365	365	365	365	365	365	365	365	365	365	365	365	365	365	365	365	365	365
8A	517	497	482	505	440	440	440	440	440	440	0	0	0	0	0	423	457	492	532	567	602	637
10	1303	1536	1100	1127	1167	1167	1167	1167	1167	1167	1167	1167	1167	1167	1167	1167	1167	1167	1167	1167	1167	1167
11	486	785	1058	767	727	727	727	727	727	727	727	727	727	727	727	727	727	727	727	727	727	727
12	1316	910	1229	1252	1070	1070	1070	1070	1070	1070	1070	1070	1070	1070	1070	1070	1070	1070	1070	1070	1070	1070
14	140	0	0	0	0	0	0	0	0	0	0	0	0	0	0	423	457	492	532	567	602	637
15	201	218	342	309	251	251	251	251	251	251	251	251	251	251	251	251	251	251	251	251	251	251
16	964	1267	1393	1302	1132	1132	1132	1132	1132	1132	1132	1132	1132	1132	1132	1132	1132	1132	1132	1132	1132	1132
16B	86	110	122	112	98	98	138	138	138	138	138	138	138	138	138	138	138	138	138	138	138	138
17	0	0	205	303	144	144	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
18	526	1354	1363	1257	963	963	963	963	963	963	963	963	963	963	963	963	963	963	963	963	963	963
19	652	619	893	762	687	687	687	687	687	687	687	687	687	687	687	687	687	687	687	687	687	687
20	0	0	0	0	208	208	348	347	278	248	337	431	506	575	655	423	457	492	532	567	602	637
21	0	0	0	0	0	0	348	347	278	248	337	431	506	575	655	423	457	492	532	567	602	637
22	0	0	0	0	0	0	0	347	278	248	337	431	506	575	655	423	457	492	532	567	602	637
23	0	0	0	0	1275	1275	1275	1275	1275	1275	1275	1275	1275	1275	1275	1275	1275	1275	1275	1275	1275	1275
24	0	0	0	0	0	0	0	0	278	248	337	431	506	575	655	423	457	492	532	567	602	637
25	0	0	0	0	0	0	0	0	278	248	337	431	506	575	655	423	457	492	532	567	602	637
26	0	0	0	0	0	0	0	0	0	248	337	431	506	575	655	423	457	492	532	567	602	637
28	0	0	0	0	0	0	0	0	0	248	337	431	506	575	655	423	457	492	532	567	602	637
30	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	423	457	492	532	567	602	637
33	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	423	457	492	532	567	602	637
37	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
38	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
39	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
40	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
41	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
42	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
43	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
44	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
45	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

APPENDIX TABLE D-3

ALTERNATIVE 3 ASSUMED ANNUAL PUMPING

2027	2028	2029	2030	2031	2032	2033	2034	2035	2036	2037	2038	2039	2040	2041	2042	2043	2044	2045	2046	2047	2048	2049	2050
45	46	47	48	49	50	51	52	53	54	55	56	57	58	59	60	61	62	63	64	65	66	67	68
23.4	24.1	24.7	25.3	25.4	25.4	25.5	25.5	25.6	25.6	25.7	25.7	25.8	25.9	25.9	26.0	26.0	26.1	26.1	26.2	26.2	26.3	26.4	26.4
671	671	671	469	472	472	476	476	479	479	483	483	486	490	490	493	493	497	497	500	500	504	483	483
0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	2	3	4	5	6	7	8	0	0
420	420	420	420	420	420	420	420	420	420	420	420	420	420	420	420	420	420	420	420	420	420	420	420
365	365	365	365	365	365	365	365	365	365	365	365	365	365	365	365	365	365	365	365	365	365	365	365
671	713	751	469	472	472	476	476	479	479	483	483	486	490	490	493	493	497	497	500	500	504	483	483
1167	1167	1167	1167	1167	1167	1167	1167	1167	1167	1167	1167	1167	1167	1167	1167	1167	1167	1167	1167	1167	1167	1167	1167
727	727	727	727	727	727	727	727	727	727	727	727	727	727	727	727	727	727	727	727	727	727	727	727
1070	1070	1070	1070	1070	1070	1070	1070	1070	1070	1070	1070	1070	1070	1070	1070	1070	1070	1070	1070	1070	1070	1070	1070
671	713	751	469	472	472	476	476	479	479	483	483	486	490	490	493	493	497	497	500	500	504	483	483
251	251	251	251	251	251	251	251	251	251	251	251	251	251	251	251	251	251	251	251	251	251	251	251
1132	1132	1132	1132	1132	1132	1132	1132	1132	1132	1132	1132	1132	1132	1132	1132	1132	1132	1132	1132	1132	1132	1132	1132
138	138	138	138	138	138	138	138	138	138	138	138	138	138	138	138	138	138	138	138	138	138	138	138
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
963	963	963	963	963	963	963	963	963	963	963	963	963	963	963	963	963	963	963	963	963	963	963	963
687	687	687	687	687	687	687	687	687	687	687	687	687	687	687	687	687	687	687	687	687	687	687	687
671	713	751	469	472	472	476	476	479	479	483	483	486	490	490	493	493	497	497	500	500	504	483	483
671	713	751	469	472	472	476	476	479	479	483	483	486	490	490	493	493	497	497	500	500	504	483	483
671	713	751	469	472	472	476	476	479	479	483	483	486	490	490	493	493	497	497	500	500	504	483	483
1275	1275	1275	1275	1275	1275	1275	1275	1275	1275	1275	1275	1275	1275	1275	1275	1275	1275	1275	1275	1275	1275	1275	1275
671	713	751	469	472	472	476	476	479	479	483	483	486	490	490	493	493	497	497	500	500	504	483	483
671	713	751	469	472	472	476	476	479	479	483	483	486	490	490	493	493	497	497	500	500	504	483	483
671	713	751	469	472	472	476	476	479	479	483	483	486	490	490	493	493	497	497	500	500	504	483	483
671	713	751	469	472	472	476	476	479	479	483	483	486	490	490	493	493	497	497	500	500	504	483	483
671	713	751	469	472	472	476	476	479	479	483	483	486	490	490	493	493	497	497	500	500	504	483	483
671	713	751	469	472	472	476	476	479	479	483	483	486	490	490	493	493	497	497	500	500	504	483	483
0	0	0	469	472	472	476	476	479	479	483	483	486	490	490	493	493	497	497	500	500	504	483	483
0	0	0	469	472	472	476	476	479	479	483	483	486	490	490	493	493	497	497	500	500	504	483	483
0	0	0	469	472	472	476	476	479	479	483	483	486	490	490	493	493	497	497	500	500	504	483	483
0	0	0	469	472	472	476	476	479	479	483	483	486	490	490	493	493	497	497	500	500	504	483	483
0	0	0	469	472	472	476	476	479	479	483	483	486	490	490	493	493	497	497	500	500	504	483	483
0	0	0	469	472	472	476	476	479	479	483	483	486	490	490	493	493	497	497	500	500	504	483	483
0	0	0	469	472	472	476	476	479	479	483	483	486	490	490	493	493	497	497	500	500	504	483	483
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	483	483

APPENDIX FIGURE D-4

ALTERNATIVES 4 AND 5 ASSUMED ANNUAL PUMPING

Production (GPM)

Date	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026
Stress Period	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44
SWTP (mgd)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.0	10	10	10	10	10	10	10
Total Pumping (mgd)	10.4	12.1	12.9	11.9	12.9	12.9	13.4	13.9	14.4	14.9	15.2	16.1	16.9	17.6	18.4	19.1	19.7	20.3	21.0	21.6	22.2	22.8
1	3	5	1	0	2	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	286
5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
6	523	555	397	409	420	420	420	420	420	420	420	420	420	420	420	0	0	0	0	0	0	0
7	500	559	367	184	365	365	365	365	365	365	365	365	365	365	365	0	0	0	0	0	0	0
8A	517	497	482	505	440	440	440	440	440	440	0	0	0	0	0	0	0	0	0	0	0	0
10	1303	1536	1100	1127	1167	1167	1167	1167	1167	1167	1167	1167	1167	1167	1167	1167	1167	1167	1167	1167	1167	1167
11	486	785	1058	767	727	727	727	727	727	727	727	727	727	727	727	727	727	727	727	727	727	727
12	1316	910	1229	1252	1070	1070	1070	1070	1070	1070	1070	1070	1070	1070	1070	1070	1070	1070	1070	1070	1070	1070
14	140	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	286
15	201	218	342	309	251	251	251	251	251	251	251	251	251	251	251	0	0	0	0	0	0	0
16	964	1267	1393	1302	1132	1132	1132	1132	1132	1132	1132	1132	1132	1132	1132	1132	1132	1132	1132	1132	1132	1132
16B	86	110	122	112	98	98	138	138	138	138	138	138	138	138	138	138	138	138	138	138	138	138
17	0	0	205	303	144	144	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
18	526	1354	1363	1257	963	963	963	963	963	963	963	963	963	963	963	963	963	963	963	963	963	963
19	652	619	893	762	687	687	687	687	687	687	687	687	687	687	687	687	687	687	687	687	687	687
20	0	0	0	0	208	208	348	347	278	248	337	431	506	575	655	0	208	208	220	248	307	286
21	0	0	0	0	0	0	348	347	278	248	337	431	506	575	655	0	208	208	220	248	307	286
22	0	0	0	0	0	0	0	347	278	248	337	431	506	575	655	0	0	208	220	248	307	286
23	0	0	0	0	1275	1275	1275	1275	1275	1275	1275	1275	1275	1275	1275	417	417	417	417	417	417	417
24	0	0	0	0	0	0	0	0	278	248	337	431	506	575	655	0	0	208	220	248	307	286
25	0	0	0	0	0	0	0	0	278	248	337	431	506	575	655	0	0	0	220	248	307	286
26	0	0	0	0	0	0	0	0	0	248	337	431	506	575	655	0	0	0	220	248	307	286
28	0	0	0	0	0	0	0	0	0	248	337	431	506	575	655	0	0	0	0	248	307	286
31	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
33	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
34	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
37	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
38	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
40	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

APPENDIX FIGURE D-4

ALTERNATIVES 4 AND 5 ASSUMED ANNUAL PUMPING

2027	2028	2029	2030	2031	2032	2033	2034	2035	2036	2037	2038	2039	2040	2041	2042	2043	2044	2045	2046	2047	2048	2049	2050
45	46	47	48	49	50	51	52	53	54	55	56	57	58	59	60	61	62	63	64	65	66	67	68
10	10	10	15	15	15	15	15	15	15	15	15	15	15	15	15	15	15	15	15	15	15	15	15
23.4	24.1	24.7	25.3	25.4	25.4	25.5	25.5	25.6	25.6	25.7	25.7	25.8	25.9	25.9	26.0	26.0	26.1	26.1	26.2	26.2	26.3	26.4	26.4
332	290	324	208	220	220	232	232	209	209	220	220	200	209	209	217	217	226	226	235	235	216	202	202
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	290	324	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	290	324	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	0	0	0	0	0	0	0	0	0	0	0	0	0
1167	1167	1167	1167	1167	1167	1167	1167	1167	1167	1167	1167	1167	1167	1167	1167	1167	1167	1167	1167	1167	1167	1167	1167
727	727	727	727	727	727	727	727	727	727	727	727	727	727	727	727	727	727	727	727	727	727	727	727
1070	1070	1070	1070	1070	1070	1070	1070	1070	1070	1070	1070	1070	1070	1070	1070	1070	1070	1070	1070	1070	1070	1070	1070
332	290	324	208	220	220	232	232	209	209	220	220	200	209	209	217	217	226	226	235	235	216	202	202
0	290	324	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1132	1132	1132	1132	1132	1132	1132	1132	1132	1132	1132	1132	1132	1132	1132	1132	1132	1132	1132	1132	1132	1132	1132	1132
138	138	138	138	138	138	138	138	138	138	138	138	138	138	138	138	138	138	138	138	138	138	138	138
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
963	963	963	963	963	963	963	963	963	963	963	963	963	963	963	963	963	963	963	963	963	963	963	963
687	687	687	687	687	687	687	687	687	687	687	687	687	687	687	687	687	687	687	687	687	687	687	687
332	290	324	208	220	220	232	232	209	209	220	220	200	209	209	217	217	226	226	235	235	216	202	202
332	290	324	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
332	290	324	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
417	417	417	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
332	290	324	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
332	290	324	208	220	220	232	232	209	209	220	220	200	209	209	217	217	226	226	235	235	216	202	202
332	290	324	208	220	220	232	232	209	209	220	220	200	209	209	217	217	226	226	235	235	216	202	202
332	290	324	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	208	220	220	232	232	209	209	220	220	200	209	209	217	217	226	226	235	235	216	202	202
0	0	0	0	0	0	0	0	209	209	220	220	200	209	209	217	217	226	226	235	235	216	202	202
0	0	0	0	0	0	0	0	0	0	0	0	200	209	209	217	217	226	226	235	235	216	202	202
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	216	202	202
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	101	101
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	101	101

APPENDIX FIGURE D-5

ALTERNATIVE 6 ASSUMED ANNUAL PUMPING

Production (GPM)

Date	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026
Stress Period	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44
Total Pumping (mgd)	10.4	12.1	12.9	11.9	12.9	12.9	13.4	13.9	14.4	14.9	15.4	16.1	16.9	17.6	18.4	19.1	19.7	20.3	21.0	21.6	22.2	22.8
1	3	5	1	0	2	2	0	0	0	0	0	0	0	0	0	400	446	480	521	555	590	638
5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
6	523	555	397	409	420	420	420	420	420	420	420	420	420	420	420	420	420	420	420	420	420	420
7	500	559	367	184	365	365	365	365	365	365	365	365	365	365	365	365	365	365	365	365	365	365
8A	517	497	482	505	440	440	440	440	440	440	0	0	0	0	0	400	446	480	521	555	590	638
10	1303	1536	1100	1127	1167	1167	1167	1167	1167	1167	1167	1167	1167	1167	1167	1167	1167	1167	1167	1167	1167	1167
11	486	785	1058	767	727	727	727	727	727	727	727	727	727	727	727	727	727	727	727	727	727	727
12	1316	910	1229	1252	1070	1070	1070	1070	1070	1070	1070	1070	1070	1070	1070	1070	1070	1070	1070	1070	1070	1070
14	140	0	0	0	0	0	0	0	0	0	0	0	0	0	0	400	446	480	521	555	590	638
15	201	218	342	309	251	251	251	251	251	251	251	251	251	251	251	251	251	251	251	251	251	251
16	964	1267	1393	1302	1132	1132	1132	1132	1132	1132	1132	1132	1132	1132	1132	1132	1132	1132	1132	1132	1132	1132
16B	86	110	122	112	98	98	138	138	138	138	138	138	138	138	138	400	446	480	521	555	590	550
17	0	0	205	303	144	144	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
18	526	1354	1363	1257	963	963	963	963	963	963	963	963	963	963	963	963	963	963	963	963	963	963
19	652	619	893	762	687	687	687	687	687	687	687	687	687	687	687	687	687	687	687	687	687	687
20	0	0	0	0	208	208	348	347	278	272	395	478	578	578	578	400	446	480	521	555	590	550
21	0	0	0	0	0	0	348	347	278	272	395	478	578	666	777	400	446	480	521	555	590	638
22	0	0	0	0	0	0	0	347	278	272	395	478	578	666	777	400	446	480	521	555	590	638
23	0	0	0	0	1275	1275	1275	1275	1275	1275	1275	1275	1275	1275	1275	1275	1275	1275	1275	1275	1275	1275
24	0	0	0	0	0	0	0	0	278	272	395	478	578	650	650	400	446	480	521	555	590	638
25	0	0	0	0	0	0	0	0	278	272	395	478	578	666	777	400	446	480	521	555	590	638
26	0	0	0	0	0	0	0	0	0	272	395	478	578	666	777	400	446	480	521	555	590	638
28	0	0	0	0	0	0	0	0	0	100	100	100	100	116	277	300	300	300	300	300	300	300
30	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
31	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
32	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	450	446	480	521	555	590	638
33	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
34	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
35	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
36	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
37	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	450	446	480	521	555	590	638
39	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
40	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
45	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

APPENDIX FIGURE D-5

ALTERNATIVE 6 ASSUMED ANNUAL PUMPING

2027	2028	2029	2030	2031	2032	2033	2034	2035	2036	2037	2038	2039	2040	2041	2042	2043	2044	2045	2046	2047	2048	2049	2050
45	46	47	48	49	50	51	52	53	54	55	56	57	58	59	60	61	62	63	64	65	66	67	68
23.4	24.1	24.7	25.3	25.4	25.4	25.5	25.5	25.5	25.5	25.7	25.7	25.8	25.9	25.9	26.0	26.0	26.1	26.1	26.2	26.2	26.3	26.4	26.4
680	729	771	451	455	455	460	460	460	460	467	467	470	475	475	478	478	482	482	486	486	490	467	467
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
420	420	420	420	420	420	420	420	420	420	420	420	420	420	420	420	420	420	420	420	420	420	420	420
365	365	365	365	365	365	365	365	365	365	365	365	365	365	365	365	365	365	365	365	365	365	365	365
680	729	771	451	455	455	460	460	460	460	467	467	470	475	475	478	478	482	482	486	486	490	467	467
1167	1167	1167	1167	1167	1167	1167	1167	1167	1167	1167	1167	1167	1167	1167	1167	1167	1167	1167	1167	1167	1167	1167	1167
727	727	727	727	727	727	727	727	727	727	727	727	727	727	727	727	727	727	727	727	727	727	727	727
1070	1070	1070	1070	1070	1070	1070	1070	1070	1070	1070	1070	1070	1070	1070	1070	1070	1070	1070	1070	1070	1070	1070	1070
680	729	771	451	455	455	460	460	460	460	467	467	470	475	475	478	478	482	482	486	486	490	467	467
251	251	251	251	251	251	251	251	251	251	251	251	251	251	251	251	251	251	251	251	251	251	251	251
1132	1132	1132	1132	1132	1132	1132	1132	1132	1132	1132	1132	1132	1132	1132	1132	1132	1132	1132	1132	1132	1132	1132	1132
550	550	550	550	550	550	550	550	550	550	550	550	550	550	550	550	550	550	550	550	550	550	550	550
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
963	963	963	963	963	963	963	963	963	963	963	963	963	963	963	963	963	963	963	963	963	963	963	963
687	687	687	687	687	687	687	687	687	687	687	687	687	687	687	687	687	687	687	687	687	687	687	687
550	550	550	550	550	550	550	550	550	550	550	550	550	550	550	550	550	550	550	550	550	550	550	550
680	729	771	451	455	455	460	460	460	460	467	467	470	475	475	478	478	482	482	486	486	490	467	467
680	729	771	451	455	455	460	460	460	460	467	467	470	475	475	478	478	482	482	486	486	490	467	467
1275	1275	1275	1275	1275	1275	1275	1275	1275	1275	1275	1275	1275	1275	1275	1275	1275	1275	1275	1275	1275	1275	1275	1275
680	729	771	451	455	455	460	460	460	460	467	467	470	475	475	478	478	482	482	486	486	490	467	467
680	729	771	451	455	455	460	460	460	460	467	467	470	475	475	478	478	482	482	486	486	490	467	467
680	729	771	451	455	455	460	460	460	460	467	467	470	475	475	478	478	482	482	486	486	490	467	467
300	300	300	300	300	300	300	300	300	300	300	300	300	300	300	300	300	300	300	300	300	300	300	300
0	0	0	451	455	455	460	460	460	460	467	467	470	475	475	478	478	482	482	486	486	490	467	467
0	0	0	451	455	455	460	460	460	460	467	467	470	475	475	478	478	482	482	486	486	490	467	467
680	729	771	451	455	455	460	460	460	460	467	467	470	475	475	478	478	482	482	486	486	490	467	467
0	0	0	451	455	455	460	460	460	460	467	467	470	475	475	478	478	482	482	486	486	490	467	467
0	0	0	451	455	455	460	460	460	460	467	467	470	475	475	478	478	482	482	486	486	490	467	467
0	0	0	451	455	455	460	460	460	460	467	467	470	475	475	478	478	482	482	486	486	490	467	467
0	0	0	451	455	455	460	460	460	460	467	467	470	475	475	478	478	482	482	486	486	490	467	467
680	729	771	451	455	455	460	460	460	460	467	467	470	475	475	478	478	482	482	486	486	490	467	467
0	0	0	451	455	455	460	460	460	460	467	467	470	475	475	478	478	482	482	486	486	490	467	467
0	0	0	451	455	455	460	460	460	460	467	467	470	475	475	478	478	482	482	486	486	490	467	467
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	467	467