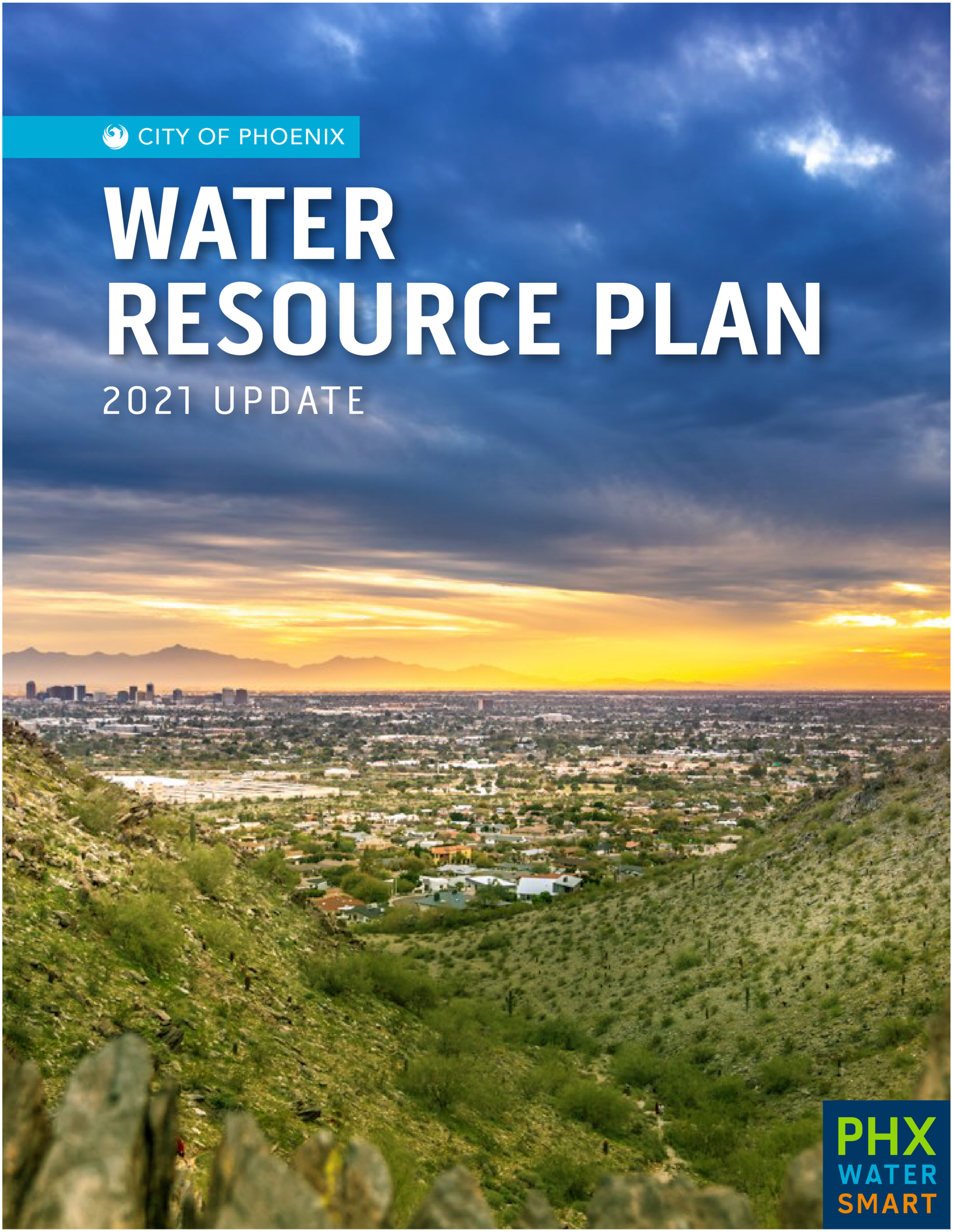
CITY OF PHOENIX

WATER RESOURCE PLAN

2021 UPDATE



PHX WATER SMART

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EXECUTIVE SUMMARY

For over 100 years, the City of Phoenix has provided clean, safe, and ample water to its residents. It serves approximately 1.7 million customers through its water utility, Phoenix Water, encompassing a service area over 520 square miles with over 7,000 miles of pipeline. During that time, Phoenix has cultivated a water supply portfolio designed to accommodate future growth and confront anticipated resource challenges based on an environment that is hot and dry. Since the adoption of the last Water Resource Plan in 2011, Phoenix has changed, and challenges to existing supplies, especially those emanating from the Colorado River, have emerged. Phoenix is continuously adapting and evolving its water resource management in response to these challenges, and the 2021 Water Resource Plan reflects the significant changes in portfolio management that have occurred since 2011.

Phoenix relies on water supplies from four primary sources: Salt and Verde watersheds delivered through canals operated by the Salt River Project (SRP); the Colorado River delivered through the Central Arizona Project (CAP); groundwater; and reclaimed water. The number of supply sources and volumes available to Phoenix annually make the Phoenix water supply portfolio both diverse and robust. Phoenix has also developed a culture of water conservation among its customers, with a commitment to efficiency and education about the value of water in the desert. Phoenix customers demonstrate that commitment through a continuing trend of declining water use – an overall per-capita reduction of 30% over the last 20 years while increasing the population by 400,000. The combination of a robust portfolio and a culture of conservation means Phoenix uses approximately 2/3 of the volume of water available to it annually, leaving a buffer for growth and expected shortage adaptation.

Phoenix water supplies were developed over time through a series of legal water rights and contracts. However, not all water supplies can be used in all parts of City's service area. Most of the water delivered by SRP from the Salt and Verde watersheds can only be used on lands that have historic membership in the SRP reclamation district, also known as "on-project lands." In Phoenix, this is generally the part of the City south of the Arizona Canal. Phoenix also has independent rights to Salt and Verde water through the construction of New Conservation Space (NCS) at Roosevelt Dam on the Salt River and control gates at Horseshoe Reservoir on the Verde River. These NCS and "Gatewater" supplies can be used anywhere in the City's service area. Phoenix has a subcontract with the federal government for Colorado River water and has long-term leases with tribes for additional Colorado River supplies. More than 3 million acre-feet (AF) of groundwater is beneath the Phoenix service area. It is foundational to the portfolio and largely reserved for periods of significant shortage. Phoenix continues to store available surface water underground, providing a supply of long-term storage credits that can be used during shortage periods. Finally, Phoenix uses most of its reclaimed water for industrial purposes, but additional supplies of reclaimed water are available now and will be available in the future as the City grows in the northern portions of the service area.

Phoenix monitors customer demand as an integral part of water resource and infrastructure planning. Currently, Phoenix is observing a decoupling of the relationship between economic and population growth and increased water use. This is attributed to the efficiencies achieved by Phoenix customers in plumbing fixtures and outdoor landscaping choices. The use of desert-adapted or native vegetation in landscaping and reduction in the construction of residential swimming pools continues to drive the water use trends downward. Phoenix has a water rate structure that applies to all classes of customers and includes price signals toward efficiency, especially during higher use periods in hotter months of the year.

Phoenix modeled several supply and demand projections through the year 2070, including scenarios with variations in the availability of supplies, growth and development and customer water efficiency or conservation. The detailed review created three specific scenarios of growth and efficiency – low, medium and high. These scenarios were then combined with supply projections for both on-project (the SRP district) and off-project (all other areas of the City). Based on the modeled scenarios, the City concludes:

- Supplies from the Salt and Verde watersheds will be resilient during the planning horizon. On-project supplies will remain ample even with expected drier climate cycles exacerbated by climate change.
- Supplies from the Colorado River are more difficult to project. While the current volume of supplies can meet anticipated demand through 2070, climate change is likely to reduce the availability of those supplies in many years. Conditions are precarious and can worsen quickly. Supplies could be further impacted by decisions regarding new Guidelines for Operation of the Colorado River expected in 2026.
- The Arizona Implementation Plan of the Lower Basin Drought Contingency Plan will mitigate any shortfalls caused by shortage conditions, so Phoenix customers will have access to full supplies through 2025.
- Shortfalls in Colorado River supplies will impact the amount of water Phoenix can store underground for future uses. Because Phoenix only uses a portion of currently available Colorado River supplies for customer consumption, reductions in available supplies after 2026 can largely be replaced by NCS supplies, Gatewater, and groundwater recovered from Phoenix's groundwater allocation or accumulated long-term storage credit account.
- As expected, the highest growth scenario results in the most significant possibility of supply deficits which would be met with additional supply development and demand management. On the other hand, the low growth scenario coupled with high water efficiency would not result in a supply deficit.

Phoenix is reevaluating the strategic use of its available water supplies in consideration of changing climate conditions, prolonged drought, and its own supply and demand modeling. There are many deficit mitigation strategies available to Phoenix, falling generally into three categories: system infrastructure improvements and regional collaboration to increase water use efficiency; demand management with additional water conservation programs; and supply augmentation of the Phoenix water supply portfolio. It is likely that initiatives from all three categories will be utilized during the planning period. It is important to have multiple strategies available, as conditions are expected to evolve over time and management flexibility will be paramount. Phoenix will take the necessary combination of actions to maintain its long-standing commitment to delivering clean, safe, and ample water to its residents through the 2070 planning period, while maintaining a water supply portfolio that can accommodate growth and climate variations that occur in the desert Southwest.

CHAPTER ONE – HISTORY AND CONTEXT

The City of Phoenix is in the Sonoran Desert, the hottest desert region in North America. The Sonoran Desert averages 3 to 16 inches of rain per year and has two precipitation seasons; one in summer with short, intense, and localized rain storms from moisture drawn up from the Gulfs of Mexico and California, and the other in winter with more widespread, gentler rains from low pressure systems moving eastward from the Pacific Ocean. Phoenix and the Salt River Valley typically average about 8 inches of precipitation per year. Periods of drought are common in the Sonoran Desert, sometimes enduring for decades.

Humans have lived in the Salt River Valley for over 3,000 years. What began with ancient peoples as agriculture and irrigation has evolved into the diverse residential, agricultural, and business activities of today. However, the key to surviving and thriving in the Sonoran Desert is the prudent development and management of water resources.

FIGURE 1. SONORAN DESERT SPRING (SOURCE: BUREAU OF LAND MANAGEMENT)

Today, large-scale water storage and distribution projects that serve the Salt River Valley support Phoenix's vibrant economy and quality of life. The Salt River Project (SRP) and Central Arizona Project (CAP) systems are the product of foresight, dedication and leadership of prior generations that recognized the economic and environmental values of managing water supplies in a desert. A complex and dynamic array of laws, regulations, policies, and institutions are as much a part of today's water management arena as the large engineering projects and hydrologic features of the watershed.

Phoenix's water resources are affected by many influences within the Valley, the state, and the regional Western United States. Issues and uncertainties regarding growth, water demands, drought, climate change, environmental needs, reservoir operations, water quality standards, groundwater management, water rights, and numerous other factors contribute to the exceptionally dynamic framework in which water resource managers must make sound planning decisions.

The Phoenix Water Services Department is the city department that is responsible for ensuring Phoenix's residents have access to a safe and reliable water supply. This commitment extends beyond current residents and utility operations to plan for future generations of Phoenicians who will need a sustainable water supply for the next 100 years and beyond.

This section will briefly discuss some of the key features of Phoenix's water planning landscape and how Phoenix assures our city has reliable water supplies for future generations.

1.1 Regional Setting

The City of Phoenix is the largest city in a metropolitan area of over 4.5 million people that includes Maricopa and Pinal Counties (Figure 2). In 2019, the population of Phoenix's water service area was approximately 1.7 million persons[1]. Phoenix's service area population represents about 38 percent of Maricopa County's residents and 23 percent of Arizona's total population. The Phoenix area economy is represented by a diverse range of industries, including a blossoming high-tech sector, financial services, and medical sector.

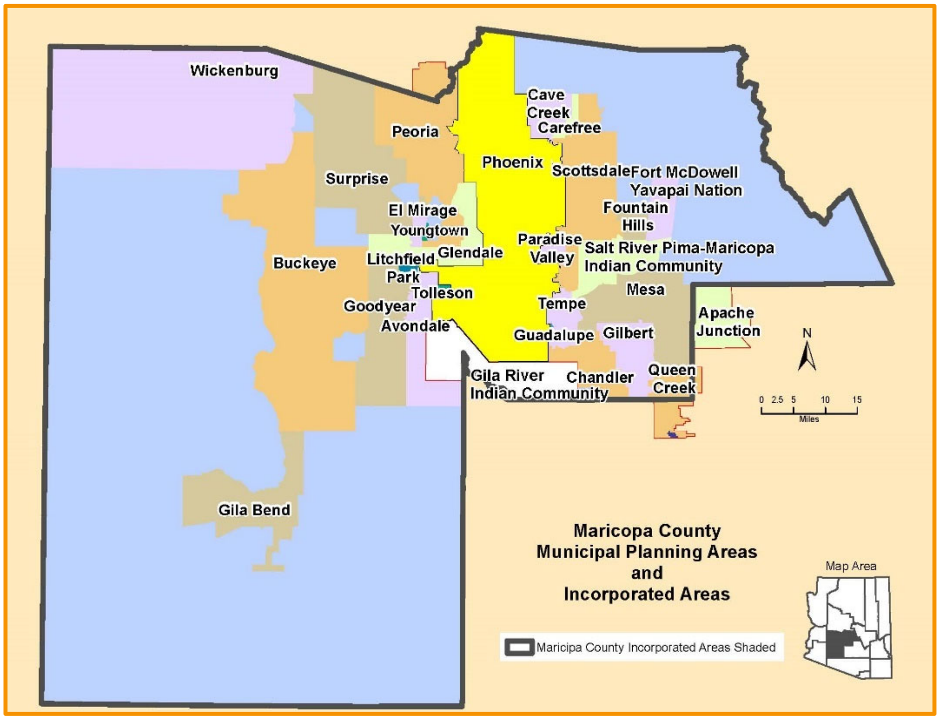

FIGURE 2. MARICOPA COUNTY CITIES AND INDIAN COMMUNITIES

Phoenix provides water service to its entire incorporated area of 519 square miles, to portions of the adjacent Town of Paradise Valley, and to nearby water service providers on a limited basis. Surrounding cities and towns typically rely on the same source watersheds or groundwater basins, though each local government maintains its own water supplies, water utilities and distribution systems. Each utility also maintains its own unique portfolio of water rights and contracts.

Growth and development patterns within the greater Phoenix metropolitan area, which covers much of Maricopa County and northern portions of Pinal County, may impact future water supply availability, density and water demand within Phoenix. Up until the mid-2000s, significant expansion of the urban area outward occurred through the construction of large master planned communities in the cities of Surprise, Buckeye, Queen Creek and Maricopa. More recently,

[1] Combines Maricopa Association of Governments estimates for the City of Phoenix and the portion of the Town of Paradise Valley served by the City of Phoenix.

residential growth occurred through infill development in Phoenix, Tempe, and Scottsdale, although expansion in the edges of the Phoenix metropolitan area is intensifying again. Also, changes in national, regional, and local populations and economics will influence type and timing of future development. These trends will shape water demands in the greater Phoenix metropolitan area.

The relationships between Phoenix area cities and Arizona's Native American Communities also add to the complexity of the local water planning landscape. Through water rights settlements, Arizona's tribal communities have rights to significant water resources and Phoenix has several long-term agreements with the tribal governments to lease or exchange water supplies to ensure continued availability of this precious resource. The futures of municipal and tribal water supplies are intertwined in Arizona.

1.2 Water Source Summary

Phoenix relies on four primary water supply sources: Salt and Verde River water, Colorado River water, groundwater, and reclaimed water. The availability of each water supply is governed by unique hydrologic, legal, and institutional factors. Salt and Verde River water is delivered to the Phoenix area through Salt River Project (SRP) canals. Colorado River water is delivered to Central Arizona through the Central Arizona Project (CAP) canal. Groundwater wells and reclaimed water make up the remainder of the City's water supplies.

The pressures on regional water supplies will increase with continuing growth in the Phoenix metropolitan area, rural Arizona, and other portions of the Colorado River Basin. Impacts of climate change have already been observed and will likely continue to exacerbate these pressures. To meet these challenges, Phoenix employs a logical and thoughtful approach to supply planning, infrastructure management, conservation, and drought preparation in a desert city. Phoenix's water sources are described in more detail in Chapter 2.

1.3 Conservation, Water Use Efficiency, and Demand Management

Water conservation, water use efficiency, and managing water demand have long been part of Phoenix's commitment to sustainability. Phoenix recognizes that these efforts must be voluntarily and willingly accepted by the public and become a shared responsibility to exercise good stewardship over our water resources. The willingness of residents to embrace and adopt water conservation and efficiency as a fundamental part of a southwestern lifestyle is essential to meet the City's commitment to maintain sustainable water resources and keep Phoenix a desirable place to live.

For over 40 years, Arizona and Phoenix have taken extraordinary steps to conserve water, improve water use efficiency, and educate residents and businesses about water use. The impacts of these efforts are significant and summarized below.

Groundwater Management Plan Municipal Conservation Requirements

The Arizona Groundwater Code, approved by the Arizona State Legislature in 1980, includes a series of five “management plans” that specify enforceable conservation targets for municipal, industrial and agricultural water users within Active Management Areas (AMAs). AMAs are geographic areas of the state that require management of groundwater in order to support growing economies. Major metropolitan areas, including Phoenix and Tucson, are within AMAs and are subject to enhanced regulation on groundwater use and conservation measures. Phoenix maintains compliance with these requirements as set forth by the Arizona Department of Water Resources (ADWR). Improvements in customer water use efficiency have reduced per-capita usage substantially during the past 30 years, allowing Phoenix to conserve more water than ADWR requires. Chapter 3 describes water demand characteristics, trends, and implications in more detail.

City Ordinances

Since the 1990s, the City has adopted ordinances similar to the State’s conservation standards for turf-related facilities and bodies of water. Turf-related facilities are defined as facilities with ten or more acres of water-intensive landscaping (i.e. grass and bodies of water) prior to 1994, and new facilities of five or more acres as of 1994. Turf-related facilities include golf courses, schools, parks, cemeteries and other miscellaneous facilities. City ordinances establish an annual water conservation allotment that is calculated based on the number of acres of turf, low water use landscaping, and water body surface area.[2]

The City sharply limits the size and content of bodies of water. Since 1994, bodies of water not part of a turf-related facility are limited to less than ¼ of an acre in size with few exceptions. If the body of water is filled with non-potable water or untreated Colorado River water, then it may be larger than ¼ of an acre.[3]

Since 1992, Phoenix requires that water delivered by Phoenix must be used to water landscaping consistent with state regulations, including a prohibition against water use for anything but low water use landscaping in public rights-of-way.[4] Low water use landscaping includes native and non-native plants and trees that have been determined by the State of Arizona to require relatively little water to grow. Prior to 1992, grass and other high water use landscaping were common along roads in Phoenix. Today, low water use landscaping is the norm.

In addition, the City has adopted regulations requiring customers to keep pipes and infrastructure on the customer side of the water meter in good repair to avoid water waste.

[2] Phoenix City Code § 37-110.
[3] Phoenix City Code § 37-111.
[4] Phoenix City Code § 37-112.

Water waste caused by water flowing from their property into the street or any public space is prohibited.[5]

Water conservation has also been incorporated into the City's Water Resources Acquisition (WRAF) fee ordinance. The WRAF is collected in certain growth areas of the City so that new development pays its proportionate share of the costs to the City that provides water to that new development. A credit can be established against the WRAF if the developer can demonstrate that the development will have features that provide permanent reduction in net annual water demand on the City.[6]

Efficiency Gains

In the 1990s, Federal requirements for minimum efficiency standards triggered significant advancements in plumbing fixture and household appliance water use efficiency and became the basis for local plumbing standards, including in Phoenix. Starting with the EPA's Energy Star program in the late 1990s and then later in the 2000s with the WaterSense program, voluntary specifications were put in place for more fixtures and appliances that exceeded minimal specifications and were marketed to the public. Clothes washers, toilets, dishwashers, and other household appliances and fixtures were widely sold under these programs. Around the same time, industrial, and commercial users began to incorporate more energy and water efficient processes and activities as part of their facility management programs, resulting in lower water demands.

Cultural Changes

In the 1980s, Phoenix began promoting water efficient landscaping. Since that time, customers have been gradually transitioning away from lawns and high water use plants, and instead towards landscaping using low water plants, shrubs and trees, and inorganic groundcover. The reasons for the customers' changing preferences vary, though reduced maintenance, lower water costs, and environmental consciousness are the most common motivations.

The cumulative effect of efficiency gains and cultural changes have resulted in a major decline in water use by Phoenix customers. While significant population growth has occurred in Phoenix since 1990, water production by the City has essentially remained flat over the same timeframe and per-capita water use has declined.

[5] Phoenix City Code § 37-27.

[6] See Phoenix City Code Chapter 30.

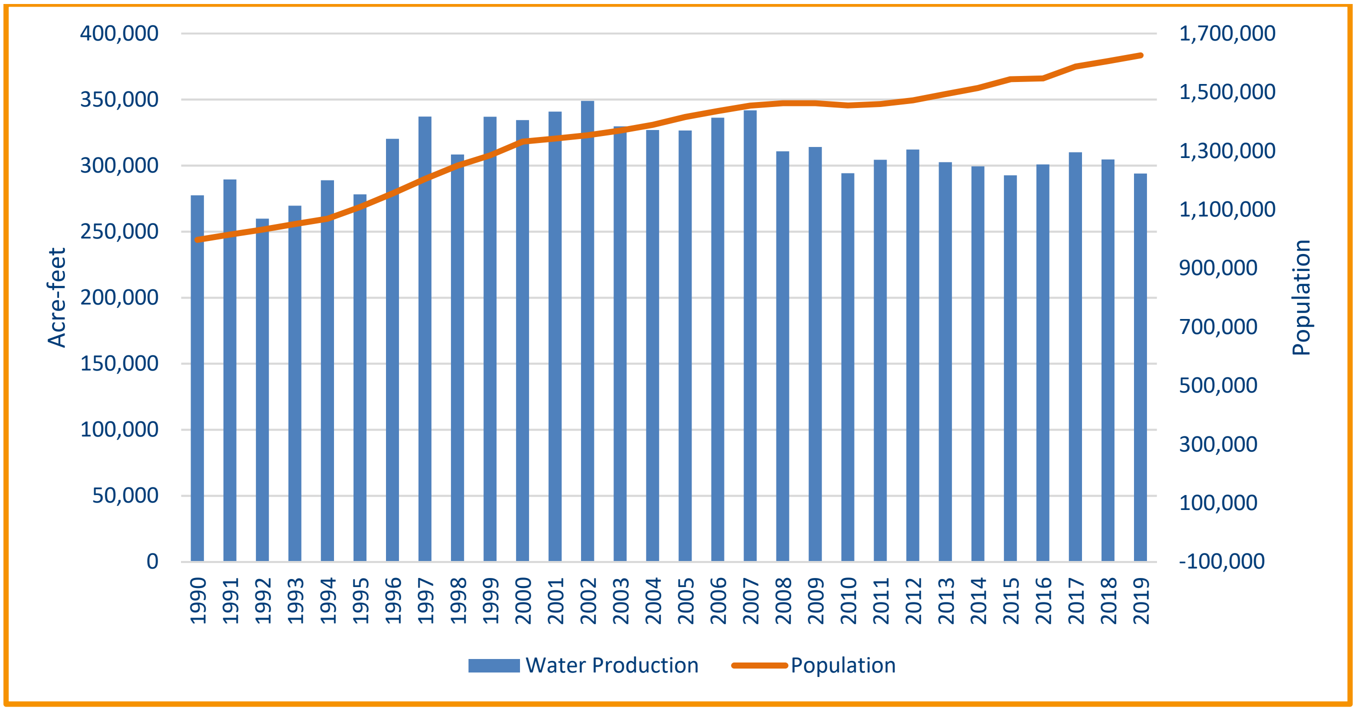

FIGURE 3. PHOENIX WATER PRODUCTION VS POPULATION GROWTH, 1990 - 2019

Demand Management

Phoenix distinguishes between two water use reduction strategies that are influenced by the availability of supplies relative to demand. The first strategy is improved water use efficiency. Phoenix emphasizes efficiency gains as a long-term culture change in the community. Residents are encouraged to embrace a desert lifestyle as a benefit to the customer and the community, and as proactive mitigation against drought conditions. While a variety of efficiency programs will be on-going during "normal" supply conditions, these efforts may be accelerated as the chance of shortage increases. Efficiency programs lead to gradual reductions in water use and do not adversely impact customer lifestyles or business opportunities. Efficiency gains prove beneficial to customers and to the City by reducing waste, reducing costs, and reducing water demands that must be met during times of drought and shortage.

The second strategy, demand curtailment, is an urgent reduction of water demand that is necessary to mitigate critical supply shortfalls. Curtailment programs can be structured to minimize customer impacts and avoid measures that impose severe impacts on a customer's quality of life and/or the local economy. Curtailment programs typically supplement, rather than replace, efforts to accelerate efficiency improvements.

If demand curtailment becomes necessary, the City will employ a triage approach to balance water demand with available supplies; first targeting discretionary water use that is not used to meet health and human safety needs. Essential water uses would be curtailed only in the most extreme supply shortfalls. The City's 2015 Drought Management Plan update describes this approach and how the City would implement demand curtailment strategies.

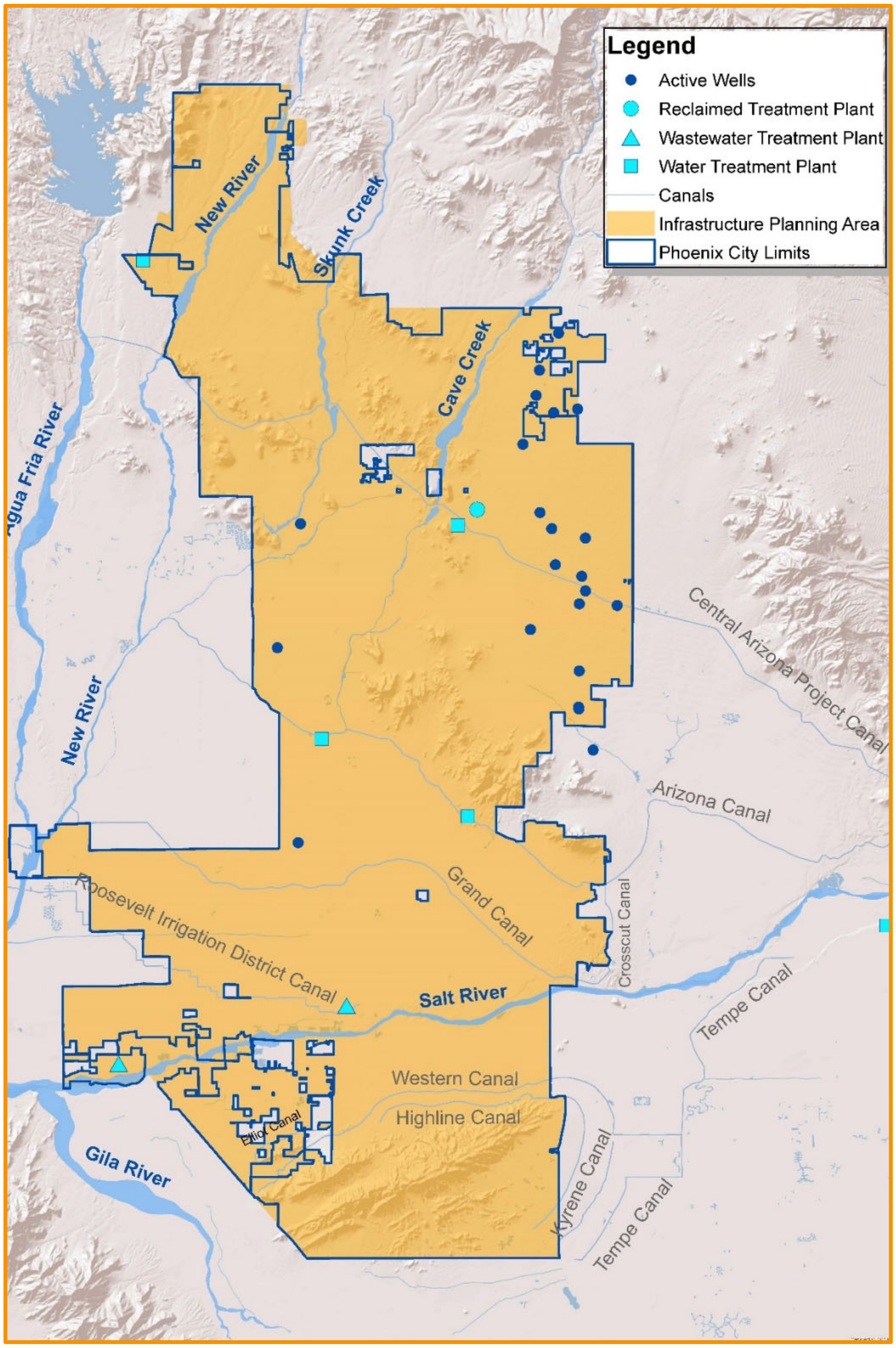

FIGURE 4. MAJOR FEATURES OF THE CITY OF PHOENIX WATER SYSTEM

1.4 An Overview of the Phoenix Water System

On July 1, 1907, the City of Phoenix officially assumed operation of the privately-owned Phoenix Water Company, which the City purchased for $150,000. Phoenix's first water system pumped groundwater from shallow wells, but the relatively brackish and poor-tasting condition of this water led to the tapping and delivery of higher quality water from the Verde River, about 30 miles east of town. The water was delivered through a redwood pipeline, which was replaced by a larger capacity concrete pipe in 1931. In the 1940s, deeper wells were drilled about 12 miles east of town.

After World War II, Phoenix rapidly grew in population and area. Significant increases in water production and system infrastructure were needed to accommodate the growth. Today, the potable water system encompasses five surface water treatment plants, dozens of pump stations and reservoirs, 7,000 miles of pipelines, 50,000 fire hydrants, and a network of groundwater wells.

Surface Water Treatment Plants

In 1947, the City's first surface water treatment plant was completed on the Verde River. As the system grew with the acquisition of several private water companies, it became clear that additional surface water treatment plants were needed. In 1952, the City entered into the "Water Delivery and Use Agreement" with SRP, which allowed water previously used for agriculture to be treated for potable purposes by the City and delivered to rapidly urbanizing farmlands in the SRP territory. Between 1952 and 1975, the 24th Street, Deer Valley, and Val Vista Water Treatment Plants were developed near the SRP canal system to provide water for urbanized lands with rights to Salt and Verde river supplies. In 2011, the Verde Water Treatment Plant was closed to avoid costly upgrades and subsequently demolished.

After completion of the CAP canal to the Phoenix area in the mid-1980s, the City opened the Union Hills Water Treatment Plant on the CAP canal in 1986. In 2007, the City began operations at the Lake Pleasant Water Treatment Plant to serve north Phoenix.

In 1990, SRP and the Cities of Chandler, Glendale, Mesa, Peoria, Phoenix, Scottsdale, Tempe and the Town of Gilbert constructed a facility to connect the CAP Aqueduct to SRP's North and South Canals near the Granite Reef Diversion Dam where the CAP and SRP canal systems intersect. The CAP/SRP Interconnection Facility, or CSIF, allows Colorado River water to be sent to Phoenix's water treatment plants on the SRP system via SRP canals. This feature significantly increases the reliability of Phoenix water supplies for both drought and short-term system needs.

Groundwater Wells

The City has developed or acquired more than 200 groundwater production wells during its history. However, since the adoption of the 1980 Groundwater Management Act, most of these wells have been removed from service due to the shift to renewable surface water supplies and well age, reduced efficiency and/or degraded water quality due to groundwater contamination.

The City currently has access to 22 active wells that can generate up to 32 million gallons of water per day (MGD). Additionally, the City has been developing new Aquifer Storage and Recovery (ASR) wells to store surface water underground for later use when needed.

Total System Capacity

The five treatment plants and active well network have a total production capacity of 638 MGD (Table 1). The plants, wells and more than 7,000 miles of water mains are designed to meet the maximum day water demands that occur during the summer months. Other facilities, such as reservoirs, booster stations, and pressure reducing valves are designed to meet "maximum day peak hour demands" and to provide emergency capacity when treatment plants or distribution components are restricted. Large transmission mains provide substantial ability to move water throughout the interconnected system, thus providing a high degree of redundancy.

TREATMENT PLANT	CURRENT CAPACITY (MGD)
Val Vista[1]	130
Deer Valley	100
24th Street	140
Union Hills	160
Lake Pleasant	80
Wells	36
TOTAL	**646**

[1]City of Phoenix share (The City of Mesa maintains 90 mgd of Val Vista capacity)

TABLE 1. CITY OF PHOENIX TREATMENT FACILITIES AND CAPACITIES

Agreements with Other Entities

Phoenix Water Services provides water to other water utilities under a variety of service agreements (treatment, wholesale and/or emergency). The Val Vista Water Treatment Plant is operated by Phoenix but jointly owned with the City of Mesa; both cities receive Salt and Verde river water from this facility. Phoenix also treats the City of Tolleson's Salt and Verde river supplies at the Val Vista Treatment Plant, which are conveyed to Tolleson through interconnections between the two systems.

More recently, Phoenix Water Services has entered into agreements to treat and deliver Colorado River supplies for the City of Avondale, the Town of Cave Creek and EPCOR in its Paradise Valley system.

Reclaimed Water Utilization

Phoenix reuses nearly all its reclaimed water for non-edible crop irrigation, cooling tower water, and aquifer recharge. The largest Phoenix wastewater treatment plant (WWTP) is the 91st Avenue WWTP. This plant is operated by Phoenix Water Services but co-owned by the Sub-Regional Operating Group (SROG), a cooperative of the five Valley cities of Phoenix, Scottsdale, Tempe, Glendale, and Mesa. In 1973, Phoenix entered into an agreement with Arizona Public Service (APS) to provide reclaimed water from the 91st Avenue WWTP to the

Palo Verde Nuclear Generating Station for cooling purposes. In addition, treated wastewater is delivered from the WWTP to the Tres Rios wetlands. The Tres Rios wetlands naturally removes nutrients and metals from the treated water. Reclaimed water from the plant is also currently delivered, via the Salt and Gila rivers, to the Buckeye Irrigation Company and Buckeye Water Conservation & Drainage District (collectively BIC) for agricultural use.

Phoenix delivers reclaimed water to the Roosevelt Irrigation District (RID) for farming purposes from the 23rd Avenue WWTP as part of a three-way exchange among Phoenix, RID, and the Salt River Project. In return for delivery of reclaimed supplies to RID, the City and the Salt River Pima Maricopa Indian Community receive Salt and Verde River supplies from SRP. The exchange is more fully discussed in Chapter 2.

In 2000, the City began delivering reclaimed water from its Cave Creek Water Reclamation Plant (CCWRP) to turf facilities in northeast Phoenix through a dedicated reclaimed water distribution system. The system delivered approximately 2 MGD to these facilities through 2010. In 2008, the national recession virtually halted growth in North Phoenix and the plant was operating well under capacity. To reduce costs, the City decided to temporarily halt production at CCWRP at the end of 2010. Production is expected to resume in winter 2024/2025, and the City is considering advanced treatment of effluent from this facility to meet the demands of customers in a part of the City served from Colorado River supplies.

1.5 Arizona's Regulatory Framework

Surface Water Rights and Regulations

In Arizona, the doctrine of prior appropriation governs the use of surface water. The doctrine is based on the tenet of "first in time, first in right", i.e. the person who first puts the water to a beneficial use acquires a right that is better than later appropriators of the water. Decreed surface water rights are those that have been determined through judicial action in a state or federal court. The most important court determination of water rights for Phoenix is the Kent Decree. The Kent Decree (*Hurley v. Abbott,* 1910) established rights to the Salt and Verde rivers for diversion by downstream landowners based on diversions occurring at that time from the Granite Reef and Joint Head diversion dams. These lands are generally the Salt River Project service area (which includes significant portions of Phoenix) and portions of the Salt River Pima-Maricopa and Fort McDowell Indian reservations. The Kent Decree established Phoenix's rights to "Normal Flow" and "Stored Water" within and delivered by the Salt River Project and described in further detail in Chapter 2. Since the Kent Decree, Phoenix appropriated additional surface water rights on the Verde River in the 1950s by constructing control gates on Horseshoe Dam ("Gatewater") and on the Salt River in the 1990s by constructing additional capacity to raise Roosevelt Dam ("New Conservation Space"). Both water resources are described in more detail in Chapter 2.

Groundwater Management

The City lies within the Phoenix AMA, one of several water planning and regulatory areas established in the 1980 Groundwater Code (Figure). This comprehensive legislation and associated regulations establish groundwater rights, conservation requirements, subdivision "assured water supply" standards and numerous other features designed to eventually eliminate the overdraft of groundwater supplies in the area. The key goal established by the Groundwater Code for the Phoenix AMA is "safe-yield" by the year 2025. This involves the balancing of groundwater withdrawals with the volume of water that recharges area aquifers. The Groundwater Code establishes specific requirements for water providers, farms, industries, and others with the intent of meeting the safe-yield target. The acquisition of Colorado River supplies and the continued use of Salt and Verde River supplies allowed Phoenix to substantially reduce its groundwater withdrawals over the decades. In the late 1970's, groundwater made up approximately 25% of the water used to meet demands in the City of Phoenix; in 2019 groundwater was less than 2% of the City's water supply.

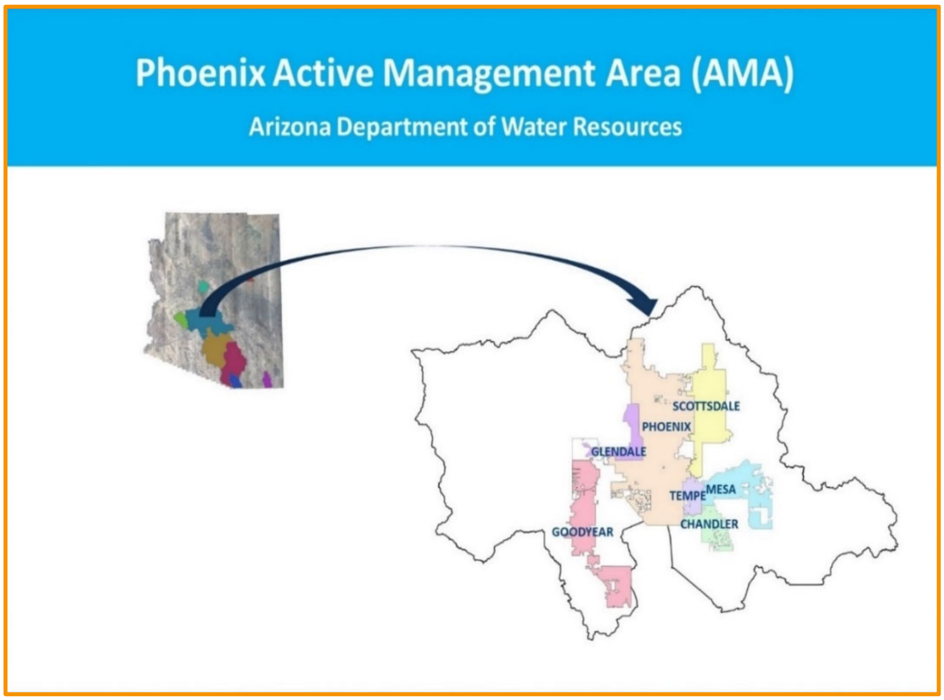

FIGURE 5. PHOENIX ACTIVE MANAGEMENT AREA

Assured Water Supply Legislation and Rules

In 1995, Arizona's Assured Water Supply (AWS) Rules became effective. These Rules require a demonstration of at least 100 years of water supplies before land can be subdivided for new development. Phoenix's success in water resource planning led the State of Arizona to grant a "Designation of Assured Water Supply" to the City in 1998. This "designation" was reconfirmed in 2010, and attests that Phoenix maintains sufficient water supplies to serve existing customers and all anticipated growth occurring through the year 2025 (the furthest date considered by the State at that time) for at least 100 years. The City's analysis, discussed later in this plan, concludes that sustainable water supplies exist for all growth currently anticipated through 2065 for at least 100 years under normal supply (non-shortage) conditions.

Recharge and Recovery Legislation and Rules

In 1986, the Arizona Legislature allowed entities with surplus supplies of surface water to store that water underground and recover it later for the entity's use under the Underground Water Storage and Recovery program. The recharge program was further defined in 1994 when the Legislature enacted the Underground Water Storage, Savings, and Replenishment Act (UWS).

Entities that wish to store water through the recharge program must apply for permits to the Arizona Department of Water Resources (ADWR), which administers the program and quantifies the amount of water stored. State law identifies two types of facility permits: Underground Storage Facilities (USFs) and Groundwater Savings Facilities (GSFs). Constructed USFs store water in the aquifer using a constructed device, such as an injection well or percolation basin. Phoenix is a partial owner in the region's first percolation basin facility, the Granite Reef Underground Storage Project ("GRUSP"), which began operations in 1994. More recently, Phoenix has developed a series of aquifer storage and recovery (ASR) wells to enhance and protect supplies in the northeast aquifer within the City. In addition, Phoenix has partnered with Tucson Water, the Metropolitan Domestic Water Improvement District in Tucson, and the City of Avondale for storage of water in their respective USFs.

A GSF allows the permit holder to deliver a renewable water supply, called "in-lieu" water, to a recipient (usually an agricultural irrigation district), who agrees to replace groundwater pumping with in-lieu water, thus creating a groundwater savings. Phoenix holds permits and has delivered reclaimed water to Roosevelt Irrigation District (RID) and surface water to SRP, New Magma Irrigation and Drainage District, and Queen Creek Irrigation District, all of which are permitted as GSFs. How Phoenix has utilized recharge as a management tool and the continuing opportunities for the City to enhance its supplies under various supply conditions in the future through recharge are discussed in Chapter 5.

Arizona Water Banking Authority

In 1996, the Arizona Water Banking Authority (AWBA) was established to increase the use of Arizona's Colorado River entitlement and to develop long-term storage credits for the state. AWBA stores or "banks" unused Colorado River water to be used in times of shortage to firm (or secure) certain water supplies for Arizona. These water supplies benefit municipal and industrial users like Phoenix, and communities along the Colorado River. The banked supplies also help fulfill the water management objectives of the state, store water for use as part of water rights settlement agreements among Indian communities, and assist Nevada and California through interstate water banking.

Beginning in 1997, the AWBA began storing Arizona's unused Colorado River entitlement underground and today, it has stored and accrued credits for over 4 million acre-feet (AF) of water for future use when backup supplies are needed. During shortage, these credits can be used to replace portions of reduced Colorado River supplies by allowing recipients of the credits to pump the water previously stored underground. Recently, the AWBA, working with ADWR, CAP, and municipal and industrial users, including Phoenix, published an updated and detailed recovery plan that clarifies how restored credits will be delivered to users when needed during shortage conditions.

Central Arizona Groundwater Replenishment District

In 1993, the Legislature created a groundwater replenishment function to be governed by the Central Arizona Water Conservation District Board of Directors throughout the tri-county CAP service area, comprised of Maricopa, Pinal and Pima Counties. This replenishment authority, commonly referred to as the Central Arizona Groundwater Replenishment District (CAGRD), provides a means for landowners and water providers to demonstrate consistency with the State's Assured Water Supply Rules where the local water provider would not otherwise be able to reconcile groundwater use with the 100-year assured water supply requirement. In effect, the CAGRD allows development to occur on groundwater supplies where subdivision lots or entire service areas have been enrolled as members. Members pay the CAGRD to obtain renewable water supplies to replenish the aquifer, although not necessarily in the same area as the groundwater withdrawals occurred. The supplies accessed by the CAGRD for replenishment purposes need not be permanently available. The CAGRD "Plan of Operation," updated and approved by ADWR in 2015, describes replenishment options and plans through 2025.

Phoenix is not a member of the CAGRD, because renewable supplies are available to the City in sufficient quantities to meet the assured water supply requirements. However, the CAGRD mechanism impacts growth patterns in the region by allowing communities with limited access to renewable water supplies to develop on locally available groundwater supplies (to a maximum depth of 1,000 feet below land surface). Much of the growth occurring in the urban fringe of the Phoenix metropolitan area is made possible by this mechanism.

CHAPTER TWO - WATER SUPPLIES AND RELIABILITY

Phoenix's water needs are met through a diverse portfolio of water supplies assembled over many decades. Supplies are commonly grouped into four major categories:

- Surface and groundwater supplies delivered through the SRP;
- Colorado River water delivered through the CAP;
- Groundwater; and
- Reclaimed water (or treated wastewater effluent).

It is important to recognize that the physical accounting for water supplies may differ from the legal accounting for water supplies due to the complex nature of the laws, regulations, agreements and water rights settlements that provide the framework for water management in Arizona. Physically, more than 95 percent of the City's demand is met with surface water (Figure 6). In years when SRP reservoirs are low, a portion of the supply may consist of groundwater pumped from SRP wells into the SRP canal system. The City also maintains a number of wells for operational flexibility and for use when Colorado, Salt, and Verde River supplies are reduced. The dynamics of these supplies under a variety of growth and drought scenarios are explored further in Chapter Four.

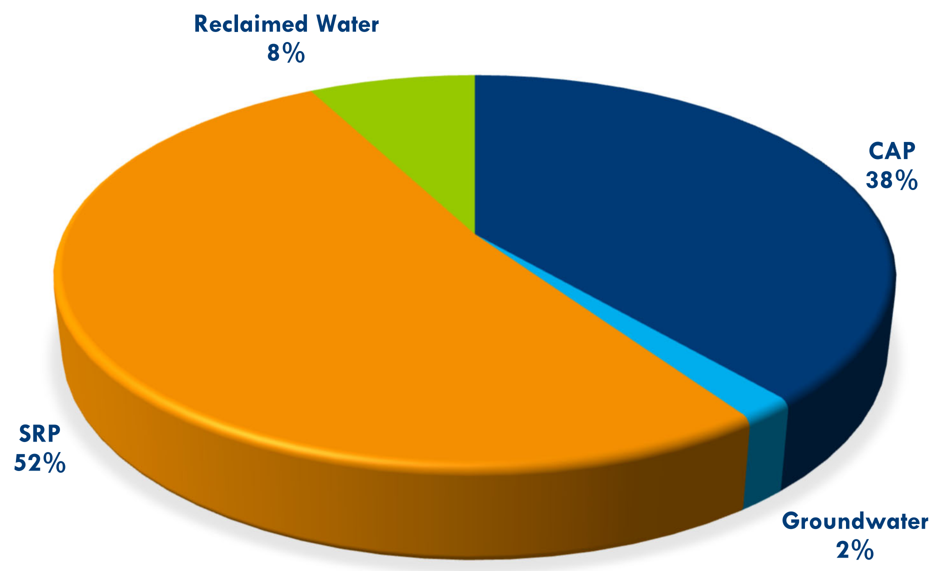

FIGURE 6. LEGAL ACCOUNTING OF PHOENIX WATER SOURCES, 2015-2019 AVERAGE

Water supplies available through both the SRP and CAP systems are based on a wide variety of water rights entitlements, contracts, leases, exchanges and other mechanisms. Supplies originating from water rights in the Salt and Verde rivers administered by SRP can be used only on lands within the boundaries of SRP ("on-project"), which includes most of Phoenix south of the Arizona Canal. All other lands within Phoenix are considered "off-project" and must receive water supplies from the Colorado River, "independent" supplies from the Verde and Salt rivers, or groundwater. The distribution of Phoenix's respective supplies adheres to the legal and contractual obligations associated with each source, but the City provides water to all customers in a seamless manner.

2.1 Supplies Available for Salt River Project Lands

Water Rights

Farming has been practiced in the Valley for thousands of years. From 1869 to the early 1900s, new settlers arrived at farmland in the area, including areas of present-day Phoenix, using the same canal network developed by ancient local Indian communities. Flows from the rivers, though, were highly variable from year to year. After passage of the National Reclamation Act (NRA) in 1902, the federal government advanced the costs for large scale reclamation projects in the western United States by loaning money to local landowners. In this way, local farmers in the Phoenix area formed the Salt River Valley Water Users' Association (SRVWUA). The "members" of the SRVWUA pledged more than 200,000 acres of their land as collateral for a government loan to build a water storage and delivery system on the Salt and Verde Rivers, including the dams operated by SRP today. In 1906, NRA authorization was extended to water rights for townsite lands, including the Phoenix townsite.

During this time, rights to Salt and Verde River supplies remained in dispute, and the federal government sought resolution of the issue. In 1910, the Kent Decree established the water rights of SRVWUA lands relative to the Salt River and its tributaries and settled conflicts between users of stored water created by the reclamation project versus owners of vested rights to the natural and normal flows of the river.

On-project water supplies restricted to SRP member lands include the following:

- Normal Flow Rights are entitlements to the unregulated or natural flow of water in the Salt and Verde Rivers as it existed before construction of SRP reservoirs and are the most senior (secure) rights on the Salt and Verde River system. Normal flow is appropriated to lands through the legal doctrine of prior appropriation. Phoenix has a relatively high proportion of SRP lands eligible for normal flow (referred to as "Class A" lands), and of these lands, a relatively high proportion had early appropriation. From 2000 to 2015, Phoenix used approximately 32,000 to 69,000 AF of normal flow per year, depending upon daily streamflow and demand. Normal flow can only be used at the time it is measured, which occurs daily.

- Stored and Developed Water is a combination of surface water stored in SRP reservoirs ("stored water") and groundwater pumped by SRP ("developed water") to supplement the surface water during drier years or for operational purposes. Each year, the SRVWUA Board sets both the total allocation and proportional mix of Stored and Developed Water that member lands receive (Table 2). Since 2015, the allocation has been 3.3 AF per acre for member land, but the SRP Board may reduce this allocation under low reservoir conditions. A reduced allocation is relatively rare, occurring in 1939, 1940, 1947, 1948, 1950, 1951, 2003, and 2004. While it is conceivable that SRP would increase the allocation during surplus conditions, this has not occurred in recent times, largely because most SRP lands are urbanized and use less than 2.0 AF per acre of water to meet demand.

YEAR	TOTAL ALLOCATION (AF/AC)	STORED WATER (AF/AC)	DEVELOPED WATER (AF/AC)
2000	3.0	2.0	1.0
2001	3.0	1.9	1.1
2002	3.0	1.7	1.3
2003	2.0	0.7	1.3
2004	2.0	0.7	1.3
2005	3.0	3.0	0.0
2006	3.0	3.0	0.0
2007	3.0	2.4	0.6
2008	3.0	3.0	0.0
2009	3.0	3.0	0.0
2010	3.0	3.0	0.0
2011	3.0	3.0	0.0
2012	3.0	2.8	0.2
2013	3.0	2.2	0.8
2014	3.0	1.8	1.2
2015	3.3	1.2	2.1
2016	3.3	1.4	1.9
2017	3.3	2.1	1.2
2018	3.3	1.8	1.5
2019	3.3	2.7	0.6

TABLE 2. SRP ALLOCATIONS AND SUPPLY MIX, 2000-2019

- Townsite Lands (those comprising the early boundaries of the Phoenix townsite) were not, as noted above, incorporated within the original Reclamation Act but were later authorized to receive supplies from reclamation projects through the Townsite Act of 1906. Phoenix's Townsite lands are almost exclusively Class A lands, which means they can receive Normal Flow in addition to Stored and Developed Water.

In addition to supplies available to SRP member lands, SRP also has contractual obligations to deliver water to other entities either because of historical obligations or Indian water rights settlements. Within Phoenix, there are three such entities. Two of them – Maricopa Gardens and New State Irrigation and Drainage District – are essentially treated as member lands. The third – the Peninsula – Horowitz Irrigation District in southwest Phoenix, is described below.

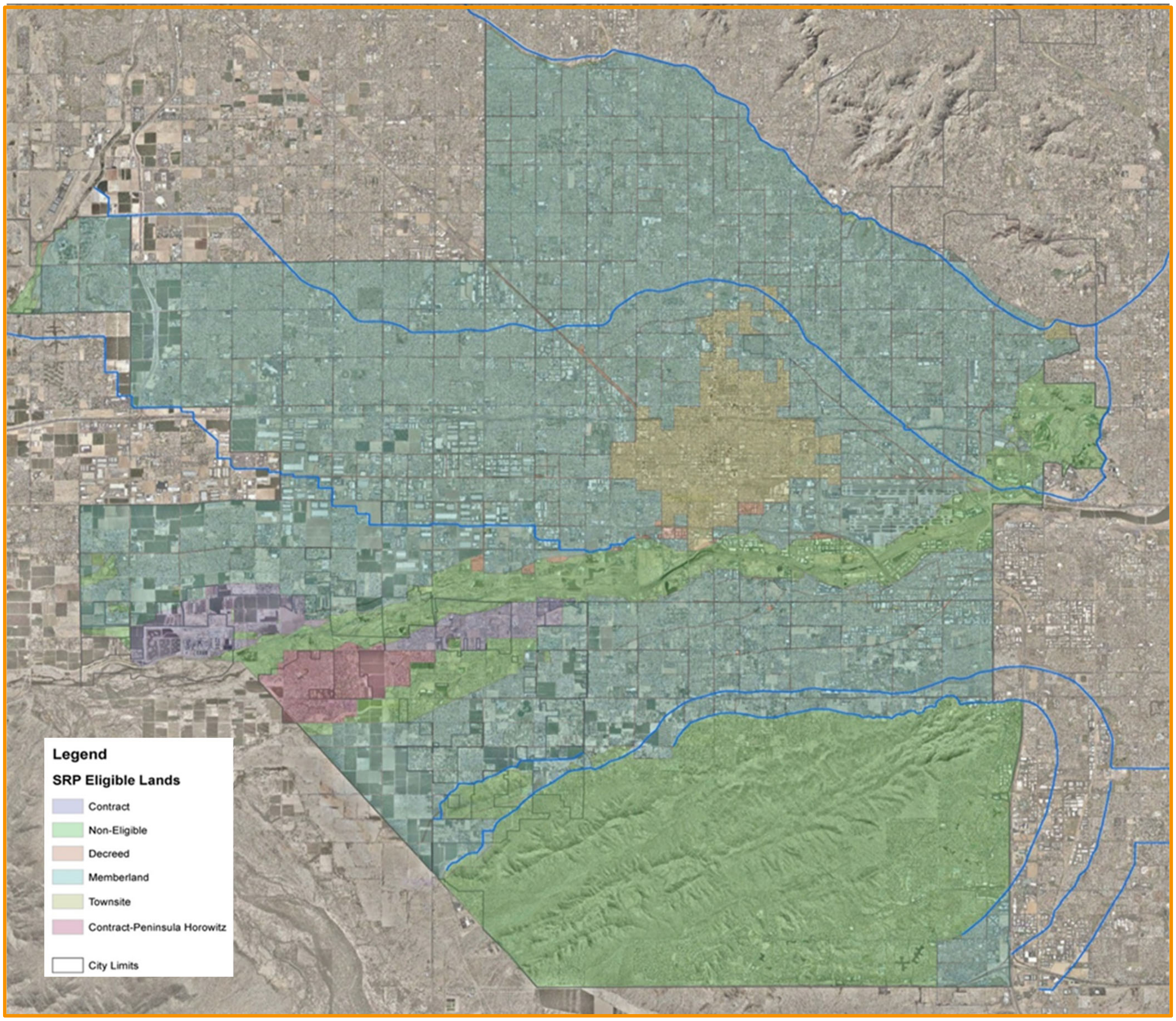

FIGURE 7. SRP LANDS WITHIN PHOENIX

Salt and Verde Watershed and River Flows

The supplies delivered by SRP originate from the Salt and Verde River watersheds, located within Arizona north and east of Phoenix along the Mogollon Rim (Figure 8). Water supplies are primarily from stream flows generated by spring runoff of snowmelt, which typically peaks each March. A secondary, but less substantial and less reliable peak in runoff can occur from intermittent monsoonal storms in the summer. Since 1900, approximately 61% of stream flows that reach the SRP reservoirs are on the Salt River watershed, with the remaining flows on the Verde River watershed, although the percentage can vary year to year.

FIGURE 8. SALT-VERDE WATERSHED

Historically, SRP reservoir system flows have varied considerably, depending on the amount of snowfall and the resulting runoff each year (Figure 9). The watershed is also characterized by extended periods of relatively wetter (higher inflow) and drier (lower inflow) periods. While the early twentieth century and the 1980s to early 1990s were relatively wet, the 1940s to 1950s and the late 1990s to today have been dry. Both extended wet and dry periods may have some years with the opposite conditions.

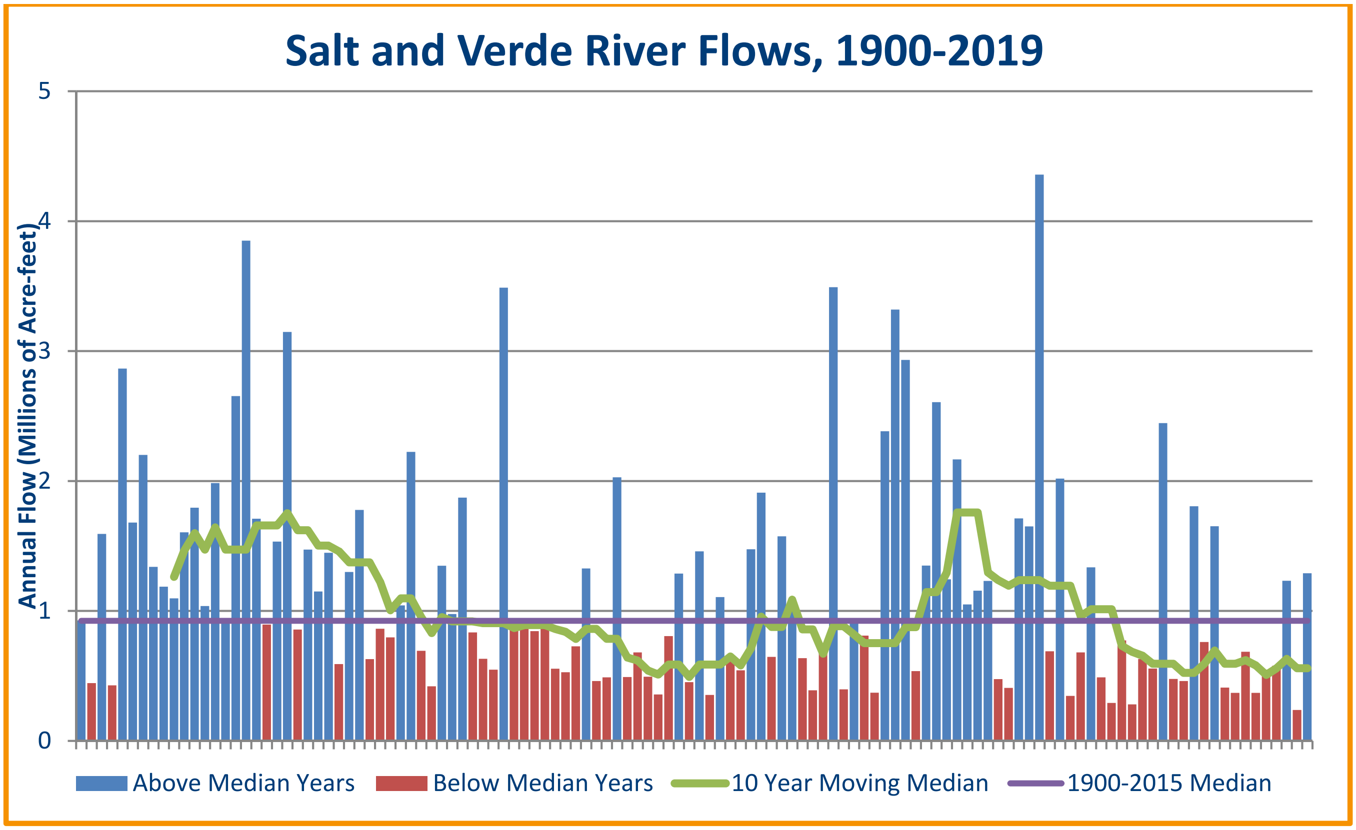

FIGURE 9. SALT AND VERDE RIVER FLOWS, 1900-2019 (SOURCE: UNITED STATES GEOLOGICAL SURVEY)

Reservoirs and Conveyance System

FIGURE 10. ROOSEVELT DAM (SOURCE: BUREAU OF LAND MANAGEMENT)

The SRP system includes six dams, two of which are on the Verde River, with the remaining four on the Salt River. Roosevelt Lake on the Salt River is the primary storage reservoir for the system, with a conservation capacity of over 2.0 million AF and a spill capacity of over 3.2 million AF (Figure 10). Total storage capacity in the SRP reservoir system is about 2.3 million AF. At the Granite Reef Diversion Dam, water from the reservoir system is released into the North and South Canals (so named because they are north and south of the Salt River and are the primary feed for member lands on the respective side of the river) into 1,300 miles of canals and laterals, so that it can be distributed to customers (Figure 11). SRP also has considerable groundwater capacity with 270 high-capacity active wells.

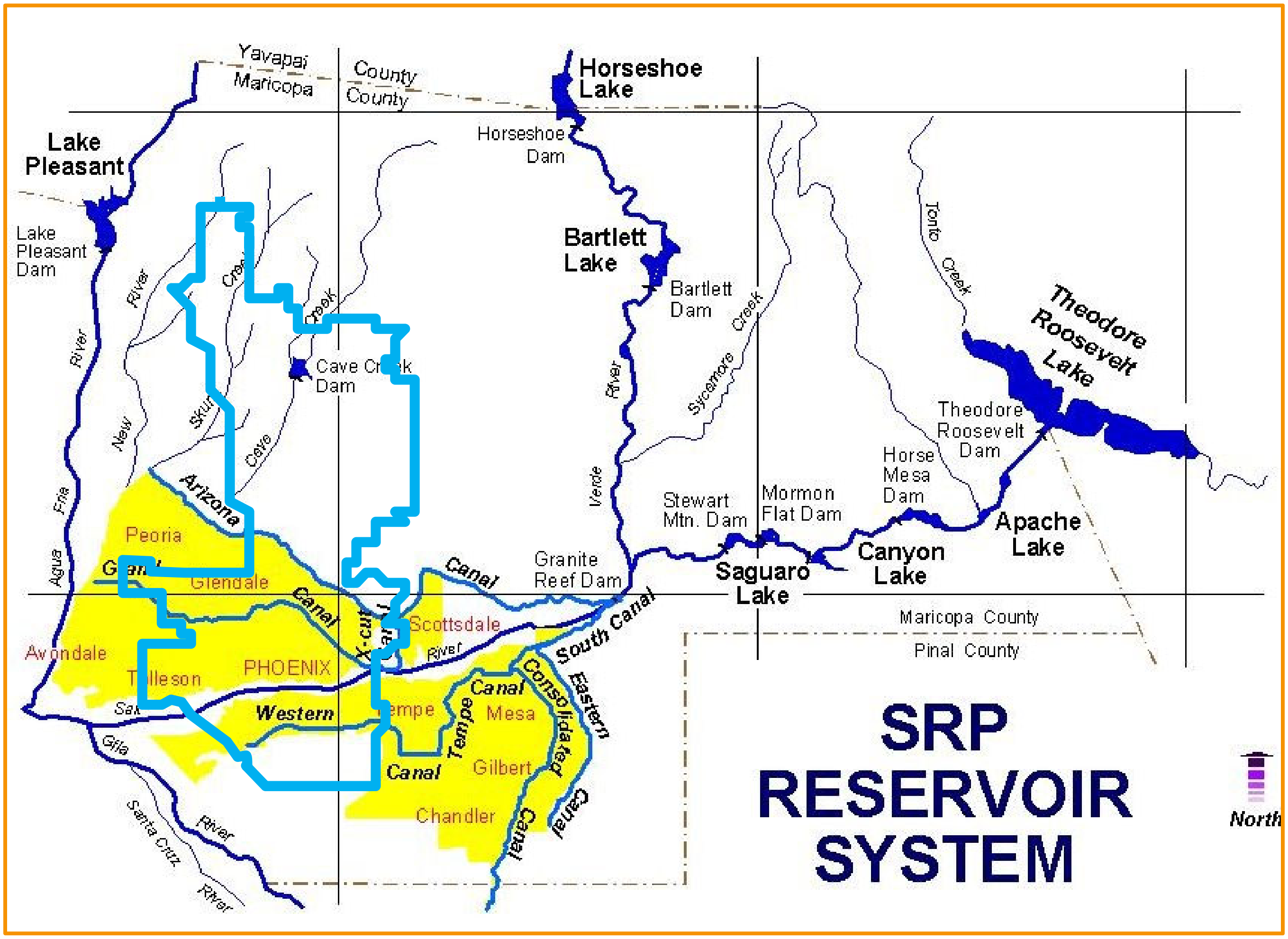

FIGURE 11. SRP RESERVOIR SYSTEM

SRP delivers approximately 700,000 AF of water per year to municipal, residential, and agricultural customers, which includes portions of several Valley cities. Deliveries for lands within the City of Phoenix encompass between 20 and 25 percent of SRP's on-project deliveries.

Water Delivery and Use Agreement

Before World War II, Phoenix relied on wells and the Verde Treatment Plant located along the Verde River in the Salt River Pima Maricopa Indian Community (SRPMIC) for water production. As SRP member lands urbanized in the City and were no longer taking direct delivery of SRP supplies, the City needed to provide treated, potable SRP supplies to these lands. In 1952, the City constructed the 24th Street Water Treatment Plant at the Arizona Canal and 24th Street to accommodate growth. At the same time, the City and SRP entered into a Water Delivery and Use Agreement (WDUA), which allowed the City to act as the agent for member lands that were no longer direct customers of SRP. SRP supplies for these lands were treated at 24th Street (and later the Deer Valley and Val Vista Water Treatment Plants). The WDUA also contains exchange provisions to address when SRP water is delivered to non-eligible lands or when City supplies other than SRP supplies are delivered to member lands. In those instances, the WDUA allows the City and SRP to exchange water from different sources to account for deliveries of SRP supplies to non-eligible lands. Some eligible lands still receive direct irrigation water deliveries from SRP in addition to potable deliveries from Phoenix.

Supply Availability for On-Project Demands

Historically, on-project water demand by Phoenix customers approached SRP's full allocation of 3.0 AF per acre for shareholder lands (see Figure 12).[7] However, there has been a gradual decline in SRP deliveries over time because agricultural lands, which tend to use more water on a per-acre basis than urban uses, have been replaced with urban uses as the Phoenix metropolitan area has grown. In addition, increasing water use efficiency by Phoenix customers has greatly reduced demand, so on-project demand is consistently below not only SRP's full allocation in recent years, but even the reduced allocations experienced in 2003 and 2004. If Normal Flow deliveries are included, the gap between supplies available to Phoenix on shareholder lands and demand is even greater. The total percentage of Normal Flow utilized each year is generally around 30-40%. If rapid infill development continues on land eligible to receive this supply, there will be enough water to sustain a large amount of densification.

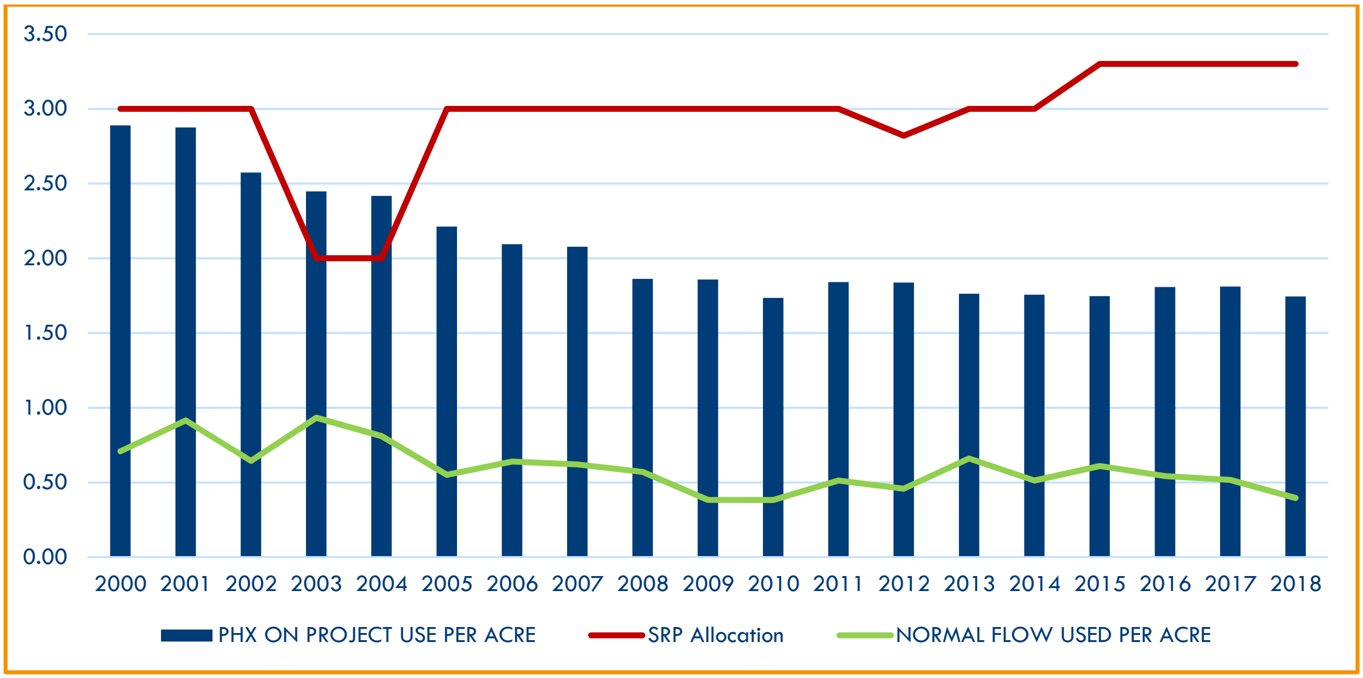

FIGURE 12. ON-PROJECT DEMAND VERSUS SRP ALLOCATION AND NORMAL FLOW DELIVERIES

Because an increasing proportion of water available in the system is not used every year, this water can remain in the reservoir system for future use. This affords SRP greater capacity to

[7] Starting in 2015, SRP adjusted its full allocation to 3.3 AF per acre.

provide water to shareholders in future years, which helps build resiliency against the effects of years with lower runoff into the reservoir system.

SRP No Charge / Spillwater

SRP occasionally experiences small-scale, low-volume storm events that enter its system. This water is referred to as "No Charge" water. Because this water is not watershed runoff that enters the reservoir system, it is not appropriated to shareholder lands because it is neither stored water nor normal flow.

During wetter years, SRP may need to release water from the reservoir system to avoid over-topping the dams. When these releases occur and are delivered to customers using SRP's canal system, significant quantities of "Spillwater" may be delivered to customers. Just like No Charge water, Spillwater is not appropriated to shareholder lands. When a No Charge or Spillwater event occurs, SRP will proportionately distribute it to the City and other shareholders amongst its deliveries. The last major spill events occurred in 2010, 2017, and 2019.

Peninsula-Horowitz Irrigation District

The Peninsula-Horowitz Irrigation District is a small irrigation district located in the Laveen area of Phoenix. The irrigation district is entitled to water because of a 1930 agreement with SRP. Although technically off-project, the Peninsula-Horowitz Irrigation District functions similarly to on-project lands in that the supplies appropriated to the district can only be used on Peninsula-Horowitz land and cannot be used elsewhere in the City. Lands within the district are appropriated up to 3.46 AF per acre from the Salt and Verde rivers, which is primarily supplied by SRP (the first two AF per acre) and then RID (the remaining 1.46 AF per acre) as demand warrants.[8] For many years, lands within the district were not urbanized; however, this changed as Laveen rapidly urbanized in the early 2000s. At that time, there was no legal mechanism for Phoenix to receive Peninsula-Horowitz water at the City's water treatment plants for urbanized lands, because Peninsula-Horowitz lands are not included in the City's Water Delivery and Use Agreement with SRP (discussed earlier in this chapter). To remedy the situation, in 2003 SRP and Phoenix executed an agreement that allowed the City to receive water and serve domestic supplies to urbanized lands within the Peninsula-Horowitz. To date, approximately 896 acres have urbanized within the district (Figure 13).

[8] Not all lands within the district are entitled to receive supplies from RID.

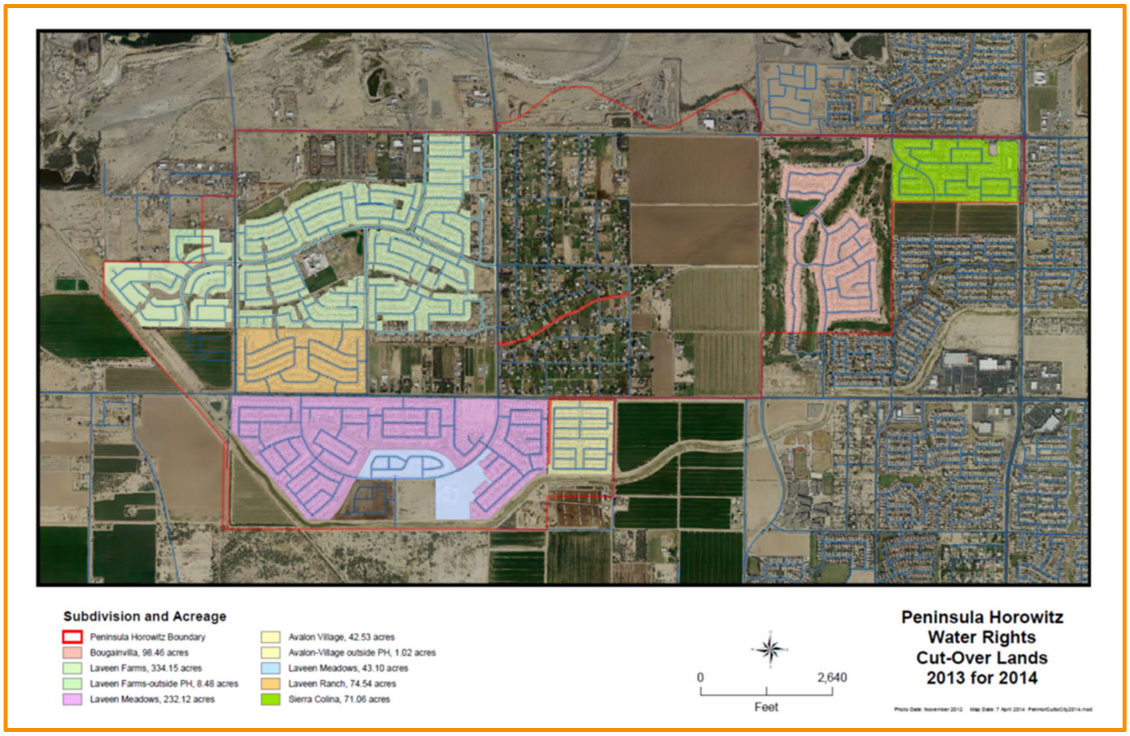

FIGURE 13. URBANIZED LANDS WITHIN THE PENINSULA-HOROWITZ IRRIGATION DISTRICT (SOURCE: SALT RIVER PROJECT)

2.2 Supplies Available to the Entire Phoenix Water Service Area

Horseshoe Dam Gatewater

From 1944 to 1946, Horseshoe Dam (Figure 14) was constructed on the Verde River by Phelps-Dodge Corporation for the Salt River Valley Water Users Association to bolster supplies in the Phoenix region in exchange for water supplies needed by Phelps Dodge's mining interests in eastern Arizona. In 1948, Phoenix, wanting to bolster its domestic supplies, entered into a contract with the Federal government and SRP and constructed gates in the dam's spillway for this purpose. Water generated by the spillway gates is an established water right for the City and is referred to as "Gatewater." The City may accrue up to 150,000 AF of credits within the SRP reservoir system and may expend up to 25,000 AF of the credits annually. Phoenix's Gatewater balance has ranged from as little as 7,600 AF, to as much as approximately 150,000 AF since 2000, and it is vulnerable to shortages on the Verde River. Over the long-term, an average of 25,000 AF is affirmed in the City's 2010 Designation of Assured Water Supply.

FIGURE 14. HORSESHOE DAM (SOURCE: BUREAU OF RECLAMATION)

Due to sedimentation over time, the amount of capacity eligible for storage has declined and this will likely continue, unless changes are made to the reservoir system. As of the 2012 survey, approximately 45,749 AF of water storage capacity had been lost. This capacity loss represents about one-third of the reservoir's original storage capacity and 15% of the total original storage capacity on the Verde River. Horseshoe Reservoir continues to lose about 1,000 AF of storage capacity per year from sedimentation. Beginning in 2020, the Bureau of Reclamation initiated a study of possible alternatives to address the sedimentation issue with its stakeholders. This will be further discussed in Chapter 5.

Roosevelt Dam New Conservation Space Water

One lesser known aspect of the Colorado River Basin Project Act was authorization for the construction of Orme Dam near the confluence of the Salt and Verde Rivers or a "suitable alternative" if the dam would not be built. Orme Dam was never built, because the dam would have submerged over half of the Fort McDowell Indian Community reservation. In 1984, the Secretary of the Interior approved "Plan 6", which raised Roosevelt Dam 77 feet and addressed flood control, dam safety, and water conservation space (Figure 15). With funding from the federal government, SRP, CAWCD, the Flood Control District of Maricopa County and the cities of Chandler, Glendale, Mesa, Phoenix, Scottsdale and Tempe, modifications to Roosevelt Dam were completed in 1996. This "New Conservation Space" (NCS) water is available when stored water on the Salt River system exceeds pre-Roosevelt Dam modification capacity. Phoenix's maximum allocated space is 136,250 AF. Since 2005, when NCS space was initially filled, Phoenix's NCS balance has ranged from approximately 84,700 AF to 136,250 AF. Over the long term, an average of 32,300 AF per year is affirmed in the City's 2010 Designation of Assured Water Supply. NCS supplies are vulnerable to shortages on the Salt River.

Roosevelt Dam Flood Control Space Water

The modification of Roosevelt Dam created additional capacity in the reservoir to protect against seasonal flooding on the Salt River. In 2019, discussions began to consider alternatives to modify the dam safety documents in order to use this reservoir capacity for short term storage space during dry seasons when floods are unlikely. Use of the flood control space at Roosevelt Dam for short term storage might provide additional access to water resources.

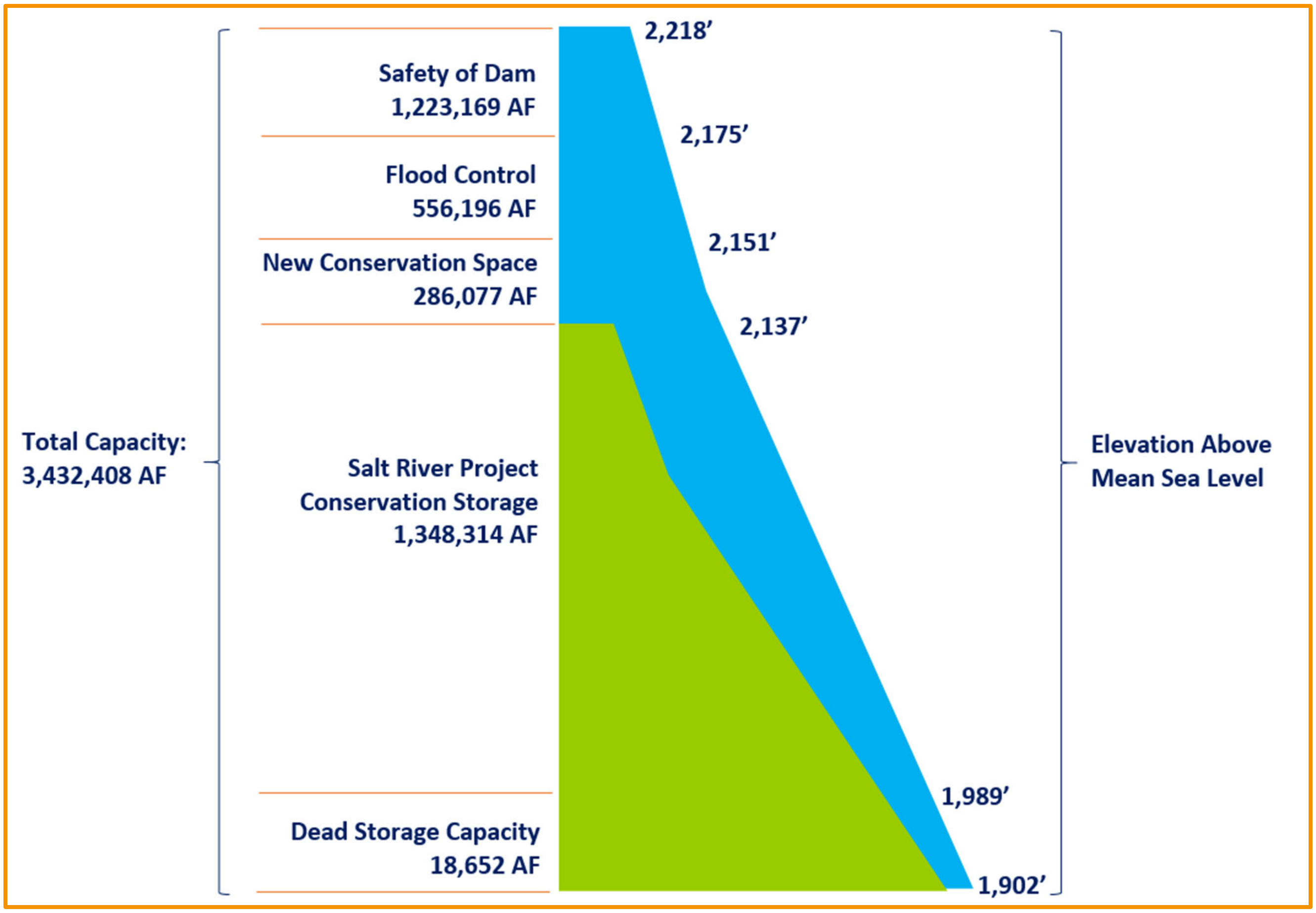

FIGURE 15. MODIFIED ROOSEVELT DAM CAPACITIES AND ELEVATIONS

Roosevelt Irrigation District "Three-Way" Exchange

One provision of the SRPMIC Water Rights Settlement Agreement laid the foundation for an agreement in 1995 that created a three-way exchange of water between the City, SRP and the Roosevelt Irrigation District (RID). For the exchange, Phoenix delivers up to 30,000 AF per year of treated effluent from the 23rd Avenue Wastewater Treatment Plant to the Roosevelt Irrigation District (RID), which delivers the water to farms in its district to grow non-food crops. RID, in turn, provides an equivalent amount of groundwater to the SRP canal system through its own wells or wells leased from SRP. SRP then credits Phoenix 2/3 of an AF and SRPMIC 1/3 of an AF for each AF of water delivered by RID to SRP (Figure 16). Using these credits, SRP delivers Salt River water to Phoenix water treatment plants served by the SRP canal system. However, Phoenix only receives supplies from SRP for what it can directly use. If Phoenix does not use all its credits each year, they may be carried over to the following year, although the amount is capped. Phoenix also may be assigned some of the SRPMIC's unused credit balance. Overall, Phoenix can carryover up to 20,000 AF of credits to the following year.

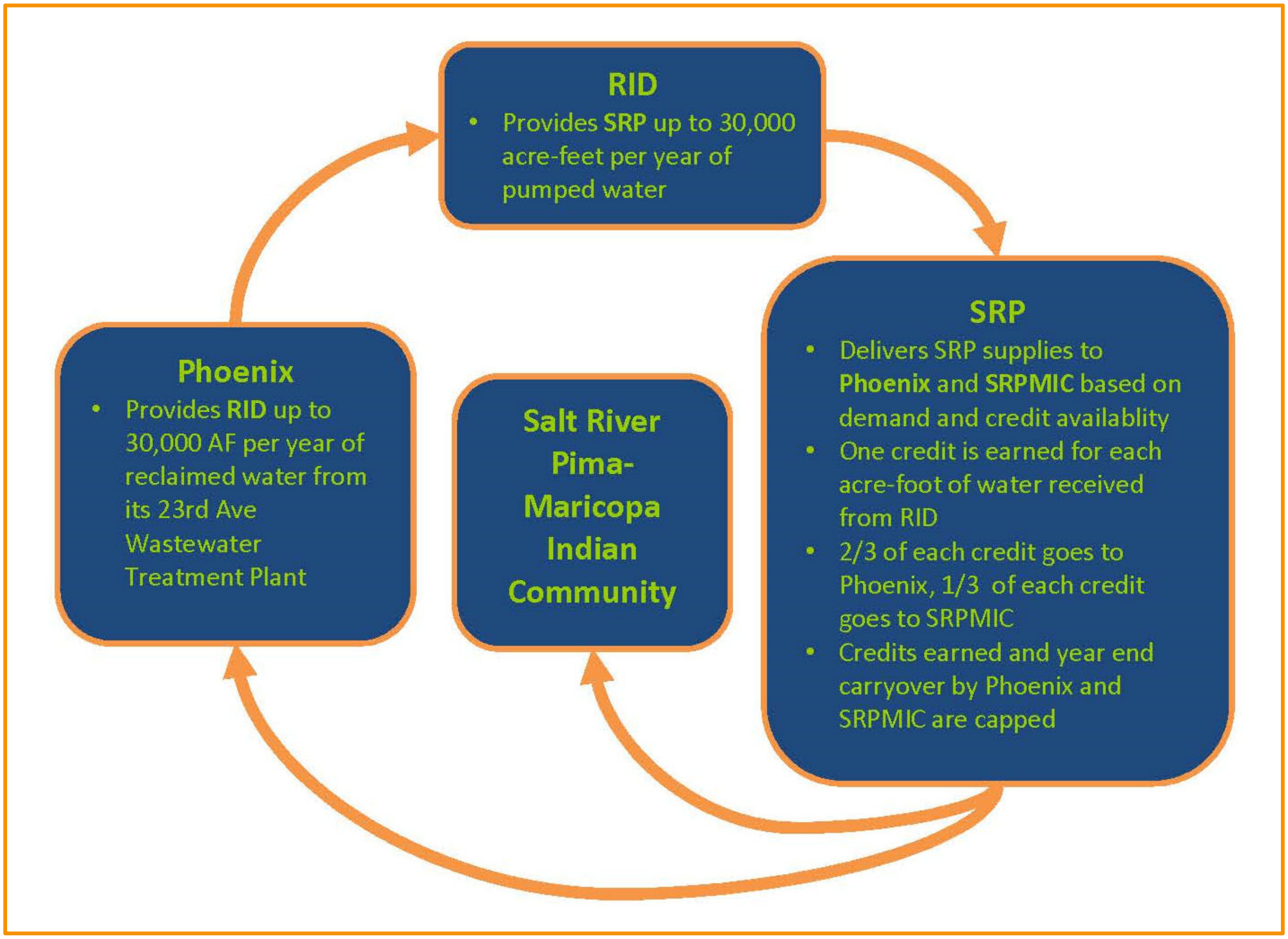

FIGURE 16. SIMPLIFIED DIAGRAM OF THE RID "THREE WAY" EXCHANGE

If SRP determines that it will reduce its annual surface water allocation to its customers due to persistent dry conditions on the Salt and Verde River systems, SRP can reduce the amount of water it receives from RID for that year. This occurred in 2003, 2004, and 2005 when SRP notified RID it would be reducing the amount of water received by RID to zero. Because Phoenix and SRPMIC only receive credit for the amount delivered to SRP by RID, neither entity earned credit during those three years. Climate change and reduced runoff may cause this phenomenon to occur more frequently in the future, although this will depend upon the balance of supply and demand by SRP customers and its contractual obligations in the future.

The water supplies Phoenix receives from SRP are treated at the three plants Phoenix operates on the SRP canal system. Because the Ahwatukee area is served by SRP plants, but is not on-project land, most of the supplies Phoenix receives from SRP as part of the exchange are used to meet the demands of the Ahwatukee area (i.e., off-project).

Colorado River Supplies

The Colorado River is highly managed and regulated through a series of compacts, federal laws, court decisions, contracts, Indian water rights settlements, and regulatory guidelines. These documents are collectively known as the "Law of the River", with the Colorado River Compact of 1922 as the foundation. The compact divided the river so that the "Upper Basin" states (Colorado, Wyoming, Utah, and New Mexico) and "Lower Basin" states (California, Arizona, and Nevada) were both given on average 7.5 million AF of water annually to develop and use. The Boulder Canyon Act of 1928 ratified the 1922 contract and apportioned 2.8 million AF annually to Arizona (4.4 and 0.3 million AF were apportioned to California and Nevada, respectively).

In 1963, the U.S. Supreme Court confirmed in *Arizona v. California* that Arizona is entitled to 2.8 million AF annually of Colorado River water, not including the flows of the Gila River system, including the Salt and Verde rivers. Five years later, Congress approved the Colorado River Basin Project Act, which included authorization for the Central Arizona Project (CAP). In 1971, the Central Arizona Water Conservation District (CAWCD) was established as the entity responsible for repaying the federal government for the costs to construct the CAP, and to manage and operate the CAP. Construction began in 1973 and the system reached Phoenix in 1985 and Tucson in 1992. The CAP aqueduct conveys surface water from the Colorado River at Lake Havasu approximately 190 miles to Phoenix. The CAP continues for another 120 miles to the system's end located south of Tucson. The system uses a series of pumps and an internal storage reservoir (Lake Pleasant) on the Agua Fria River. The canal was designed to convey 1.5 million AF for contract deliveries but is capable of carrying up to 1.8 million AF per year when supplies are available (Figure 17).

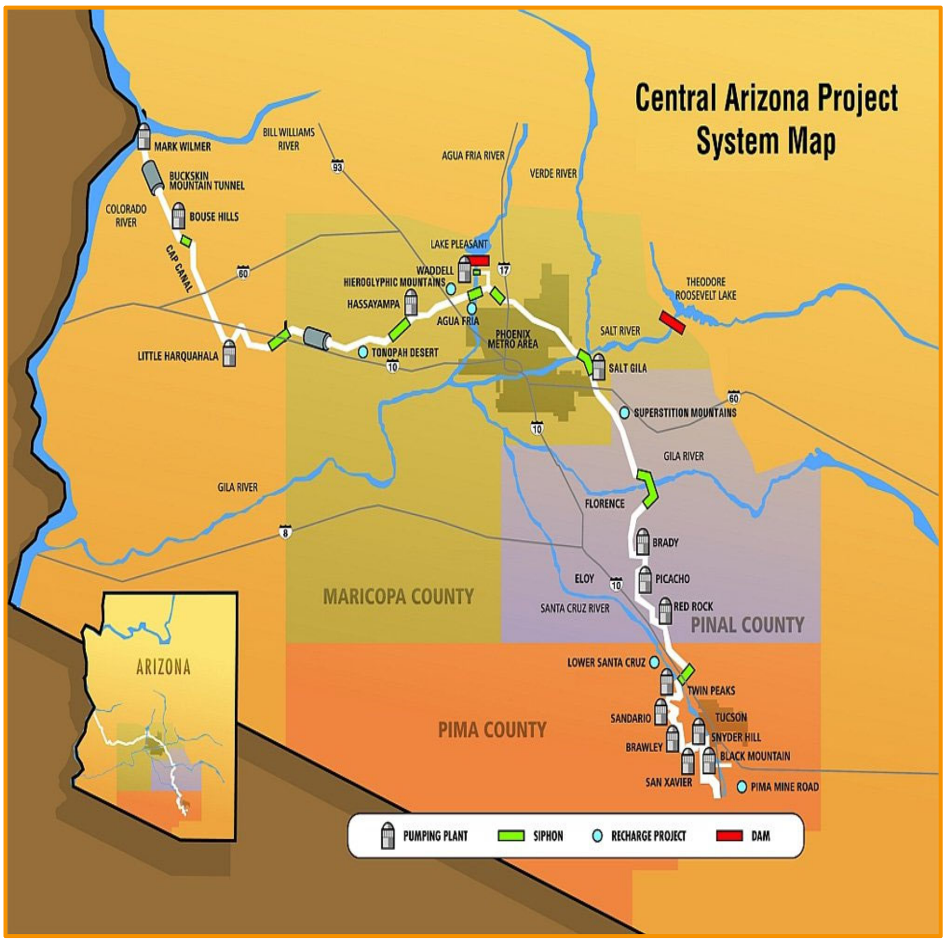

FIGURE 17. CENTRAL ARIZONA PROJECT SYSTEM AND INFRASTRUCTURE (SOURCE: CENTRAL ARIZONA PROJECT)

The Colorado River Basin Project Act, in addition to authorizing CAP, made most of the Colorado River water delivered into Central Arizona through the CAP subordinate to California's apportionment during shortages.

While most of the water rights in the Salt and Verde rivers delivered through SRP are limited to use in certain geographic areas of the City (on-project), Colorado River water delivered through the CAP to Phoenix can be used anywhere within the City's service area. Most of the Colorado River water Phoenix receives is pursuant to a subcontract with the Central Arizona Water Conservation District and the U.S. Secretary of the Interior, who functions as the "Watermaster" for the Lower Basin of the Colorado River. The subcontract is through perpetuity with a 100-year delivery term.

FIGURE 18. CENTRAL ARIZONA PROJECT AQUEDUCT (SOURCE: BUREAU OF RECLAMATION)

Colorado River supplies have an established set of priorities. The highest priority supplies are Priority 1 through 3 supplies, which were legally established before the passage of the Colorado River Basin Act of 1968. These supplies are generally used by California and by the cities, tribes, and agricultural districts in Arizona that are located on the Colorado River. Some Priority 3 supplies that belonged to the Wellton-Mohawk Irrigation District near Yuma were reallocated through water rights settlements to Municipal and Industrial (M&I) and Indian users in Central Arizona, including Phoenix, and are delivered through the CAP system. These are the highest priority supplies delivered through the CAP. The remainder of the Colorado River water delivered through the CAP is within Priority 4 of Arizona's Colorado River entitlement,[9] and can be reduced during declared shortages on the Colorado River before priorities 1 to 3 water are reduced. Within Priority 4 supplies, there are also priorities for delivery. Municipal and Industrial (M&I) subcontracts and Indian contracts have the highest priority of supplies and are second in priority only to Priority 3 supplies delivered through the CAP.

Next in priority behind M&I and Indian priority water is a category of water referred to as Non-Indian Agricultural (NIA) priority water. This water was originally allocated to the agricultural districts of Central Arizona. Beginning in the 1990s, agricultural irrigation districts either relinquished or terminated their contracts, primarily due to the cost of water. This shift in

[9] CAWCD is allocated "the balance of Arizona's entitlement" with an estimated diversion of 1.49 million AF per year.

supplies culminated in the Arizona Water Settlements Act (AWSA) of 2004, in which many agricultural districts within Central Arizona relinquished their long-term contracts to Colorado River water in exchange for access to available excess water in subsidized deliveries through 2030 (see below). The AWSA reserved 197,500 AF of this relinquished Non-Indian Agricultural (NIA) priority water to the Secretary of Interior for settlement of Indian water rights claims, while another 96,295 AF was reserved for ADWR to recommend a reallocation by the Secretary to M&I users.[10]

Any Colorado River water available that is not used, resold, or exchanged pursuant to long term contracts and subcontracts is called excess water, and can be used by CAWCD for any authorized purpose of the Central Arizona Project. It is the lowest priority water within the Priority 4 water available through the CAP. Generally, the CAWCD determines which entities in central Arizona are allowed to order excess water, and in which quantities; however, the price is set at the “full cost” of CAP water, generally equal to the sum of the capital, operating, and energy charge for CAP water. Pursuant to the AWSA, CAWCD agreed to make the first 300,000 AF of excess water per year available to agricultural districts from 2017 to 2023, and 225,000 AF per year available from 2024 to 2030. Although still excess water priority, this water is commonly referred to as “agricultural pool” water and there is no obligation to make excess water available to these districts as an “agricultural pool” beyond 2030. It is important to note that while the water made available to the districts under this arrangement is heavily subsidized, it is only available to the districts after demands for M&I, Indian and NIA priority water held under long-term contracts are met, and is the first water subject to reductions in deliveries during shortage conditions. Figure 19 illustrates the priorities of supplies delivered through the CAP System by CAWCD.

During the early years of the CAP, there was generally less demand for Colorado River water in Central Arizona than supplies available. Excess water was made available to any entity in Central Arizona that wished to purchase it, including cities, golf courses, industrial users, private equity firms, and other miscellaneous users. At the time, the Arizona Water Banking Authority purchased the available excess water and stored it in aquifers as a hedge against future shortages and to ensure that California did not gain access to Arizona’s water. However, beginning in 2015, as demand for Colorado River water in Central Arizona has outstripped supplies available, excess water has largely been made available only to the AWBA and CAGRD after meeting the “Agricultural Pool” requirements of the AWSA. In 2019, this practice was adopted as a CAWCD Board Policy.[11]

[10] In 2014, ADWR recommended reallocating 46,629 AF to the Secretary of the Interior. The City of Phoenix did not seek nor was recommended a reallocation in this process. These allocations should be finalized in 2021 for first use during water year 2022.

[11] “Procedure for Distributing CAP Excess Water and Turn-Back Water for the Period of 2020 through 2024,” September 5, 2019: file:///C:/Temp/CAWCD-Procedures-to-Distribute-Excess-Water-and-Turn-Back-Water-in-2020-through-2024.pdf.

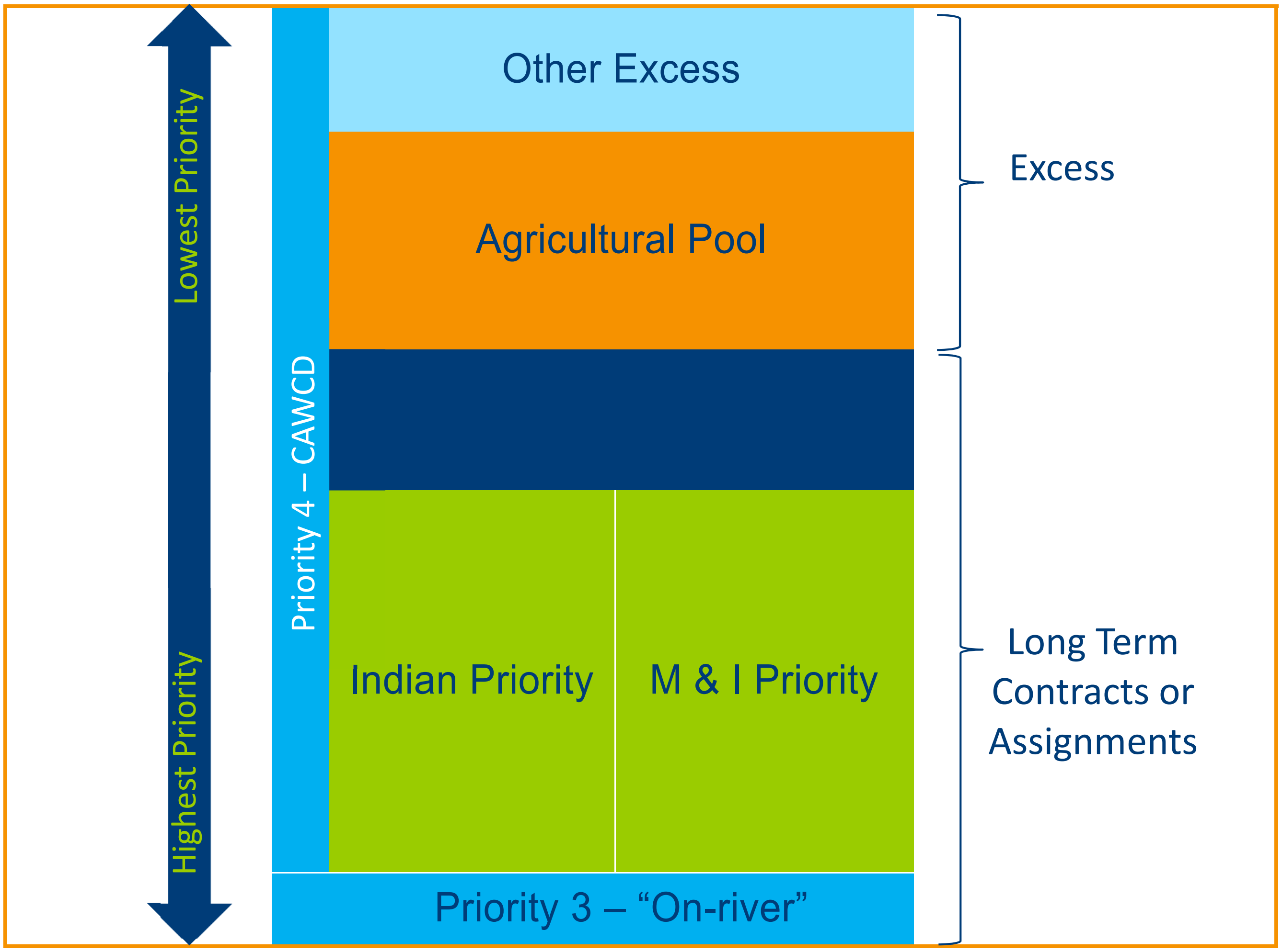

FIGURE 19. COLORADO RIVER SUPPLIES BY PRIORITY DELIVERED BY CAWCD

The City of Phoenix has access to a total of 186,557 AF of Colorado River water. These supplies are available to Phoenix through both long-term contracts and leases with Indian communities. Most of the water is considered Priority 4 or is "high priority" within CAP's priority system. Colorado River supplies are summarized as follows and are illustrated in Table 3.

WELLTON MOHAWK IRRIGATION AND DRAINAGE DISTRICT (WMIDD)

As part of the Salt River Pima-Maricopa Indian Community (SRPMIC) Water Rights Settlement Agreement, Phoenix was assigned 4,750 AF per year of "on-river" Colorado River water from this district located in southwest Arizona (after deducting losses). At Priority 3, this supply is the highest priority of Phoenix's Colorado River supplies.

MUNICIPAL AND INDUSTRIAL SUBCONTRACT

Phoenix's Municipal and Industrial (M&I) subcontract provides for delivery of up to 122,204 AF of water per year. After Priority 3 water, M&I subcontracts are among the highest priority allocations (last to be reduced) within the CAWCD's supply structure.

INDIAN LEASES

The City maintains long-term leases with the Fort McDowell Indian Community (FMIC), SRPMIC, and the Gila River Indian Community (GRIC) for a combined total of 22,323 AF per year. These leases are a result of water rights settlements with each respective community. Indian Priority water is similar in priority to M&I water, which means the supplies have the highest priority within CAWCD's system after Priority 3 water. These leases have respective terms of 100 years. Collectively, these high priority supplies account for approximately 80 percent of the Colorado River supplies available to Phoenix.

WHITE MOUNTAIN APACHE INDIAN LEASE

According to the terms of the White Mountain Apache Tribe (WMAT) Water Rights Quantification Agreement, Phoenix will lease 3,505 AF of CAP water allocated to the White Mountain Apache community. This agreement was approved by Congress in December 2010. Currently, it is uncertain when the agreement will be implemented and the water available to the City.

HOHOKAM IRRIGATION AND DRAINAGE DISTRICT (HIDD) WATER

In 1987, the federal government abandoned a plan to construct Cliff Dam along the Verde River. In lieu of this supply, in 1993, Phoenix along with the Cities of Chandler, Mesa and Scottsdale, entered into an agreement with the HIDD to acquire some of its CAP allocation, pursuant to the FMIC Water Rights Settlement. HIDD water is NIA priority water through 2043, when the supply converts to M&I priority. The long-term contract provides for 36,144 AF per year.

ROOSEVELT WATER CONSERVATION DISTRICT (RWCD) ASSIGNMENT

The City also has access to another 1,136 AF of NIA Priority water that was assigned to Phoenix by the RWCD as part of the SRPMIC Water Rights Settlement Agreement. As they are both currently NIA Priority supplies, HIDD Assignment Water and RWCD Assignment Water are Phoenix's most vulnerable supplies during Colorado River shortages.

ARIZONA STATE LAND WATER

In the mid-1980's, the Arizona State Land Department (ASLD) received a Municipal and Industrial (M&I) subcontract from CAWCD for Colorado River Water. Although ASLD was not then, and will not ever be, a water provider, the purpose of the subcontract was to allocate water for state lands that would eventually be incorporated into municipal service areas. The subcontract included an appendix that described the volumes and cities that would ultimately receive the water through transfers of the subcontract amounts from ASLD. Based on that subcontract and appendix, Phoenix expects to receive a transfer of a contractual right to 12,000 AF annually of M&I priority Colorado River from ASLD to serve customers in an area located north of Jomax Road. In 2020, the City and ASLD agreed to the incremental transfer of the 12,000 AF over a period of four years, and in 2021, ASLD initiated the first transfer of 3,900 AF to the City through the action of the State Selection Board.

CAP / SRP INTERCONNECT FACILITY

Under normal operations, Colorado River supplies are delivered to the City's Union Hills and Lake Pleasant Water Treatment Plants, which provide north Phoenix's domestic supplies. However, Colorado River supplies are occasionally conveyed to the City's other water treatment plants by way of the CAP/SRP Interconnect Facility (CSIF), which connects the CAP Aqueduct to the SRP canal system. The 1993 CSIF Agreement entitles Phoenix to use 38.425 percent of the total capacity of the CSIF, although the City's capacity for each component of the facility (Arizona Canal, South Canal, Salt River bed, and the Common Facility) varies. The CSIF is also used to deliver Colorado River supplies for aquifer recharge at the Granite Reef Underground Storage Project, which is discussed in more detail later.

SUPPLY	PRIORITY 3	INDIAN & M&I PRIORITY	NIA PRIORITY	TOTAL
M&I SUBCONTRACT		122,204		122,204
HIDD ASSIGNMENT[1]			36,144	36,144
WMIDD ASSIGNMENT[2]	4,750			4,750
FMIC LEASE[3]		4,300		4,300
GRIC LEASE[4]		15,000		15,000
SRPMIC LEASE[5]		3,023		3,023
RWCD ASSIGNMENT[2]			1,136	1,136
TOTAL	**4,750**	**144,527**	**37,280**	**186,557**
WMAT LEASE[6]		3,505		3,505
AZ STATE LAND[7]		12,000		12,000

[1] Acquired in 1992 in lieu of Cliff Dam pursuant to the Fort McDowell Indian Water Rights Settlement. Beginning 2044, converts to M&I priority.
[2] Assigned to Phoenix in 1998 pursuant to the Salt River Pima Maricopa Indian Community Water Rights Settlement. Assumes a five percent system loss.
[3] Leased until 2100 pursuant to the Fort McDowell Indian Community Water Rights Settlement.
[4] Leased until 2108 pursuant to the Gila River Indian Community Water Rights Settlement.
[5] Leased until 2098 pursuant to the Salt River Pima Maricopa Indian Community Water Rights Settlement.
[6] Approved by Congress 2010, but funding is subject to expiration if not completed by 2022. If implemented, Phoenix CAP supplies would total 190,062 AF AF.
[7] To be assigned to Phoenix through incremental transfers over four years beginning in 2021 to serve development of State Trust lands north of Jomax Road in the Phoenix service area.

TABLE 3. PHOENIX COLORADO RIVER SUPPLIES

Colorado River Watershed and Inflows

Similar to the Salt and Verde Rivers, inflows created by runoff and then streamflow into the Colorado River system have varied considerably from year to year (Figure 20) and the watershed is also characterized by extended periods of relatively wetter (higher inflow) and drier (lower inflow) periods. While the early twentieth century and the 1980s were relatively wet, the 1930s to 1950s and the 1990s until today have been characterized by a record drought period. Both extended wet and dry periods may have some years with the opposite conditions.

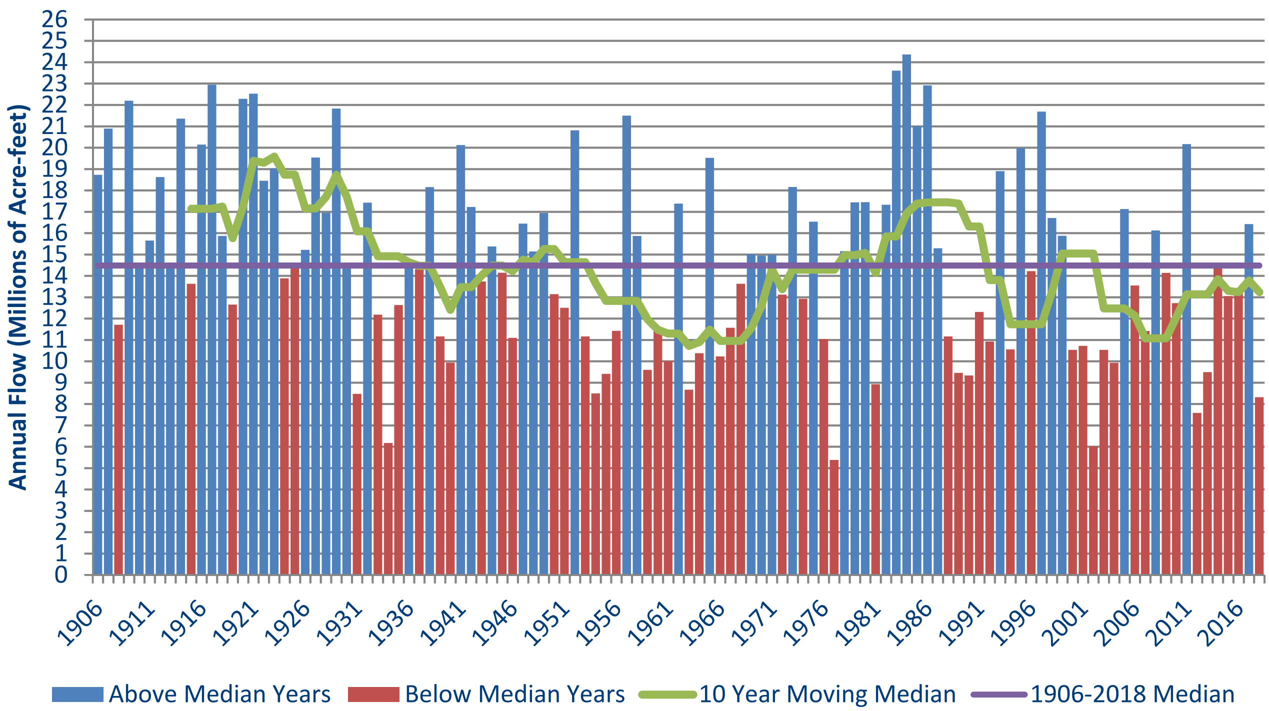

FIGURE 20. COLORADO RIVER LOWER BASIN INFLOWS, 1906-2018 (SOURCE: BUREAU OF RECLAMATION)

2.3 Surface Water Reliability and Management

Cyclical Drought on the Watersheds

Yearly fluctuations in precipitation and snowmelt, also known as the El Niño/ Southern Oscillation (ENSO) cycle, are common in Southwest river systems. In the short-term, these changes are affected by oceanic fluctuations in sea-surface temperatures, surface air pressure, convective rainfall, and atmospheric circulation.

There are two extremes in the ENSO cycle: El Niño and La Niña. Lasting approximately 6 to 18 months, El Niño is the warm phase of the cycle and characterized by above-average sea-surface temperatures across the east-central equatorial Pacific. This tends to result in stormy spring and winter weather in the southern United States due to an enhanced southern jet stream. On the opposite extreme is La Niña, which is associated with a cooling of sea-surface temperatures also along the east-central equatorial Pacific. This pulls storm tracks more north, which results in drier conditions in the Salt and Verde Rivers Basin watershed. In contrast, El

Niño often leads to higher than average precipitation events. The significantly larger and more northerly Colorado River basin watershed can be positively or negatively influenced by either event. [12]

Another pattern of climatic variability is the Pacific Decadal Oscillation (PDO), which also has warm and cool phases that can each last 20 to 30 years. According to experts, ENSO cycles occurring within these PDO phases can potentially be amplified if they are aligned and weakened if they are in opposite phases. In the latter event, this may prevent "true" La Niña/ El Niño impacts from occurring.[13]

The long-term fluctuations occurring in short- and long-term frequencies as a result of the ENSO cycle, the PDO, and other climatic influences are evidenced by both recent historical measurements and reconstructed flows based on tree ring research. When 5- to 10-year running averages are used to smooth the annual variations in this data, longer term cycles are observed that transition between wet and dry periods that can endure for many decades (Figure 21). The past 100 years of recorded flows do not exhibit such lengthy shortages, and thus prior water resource planning efforts in the West have likely underestimated the potential length and intensity of drought.

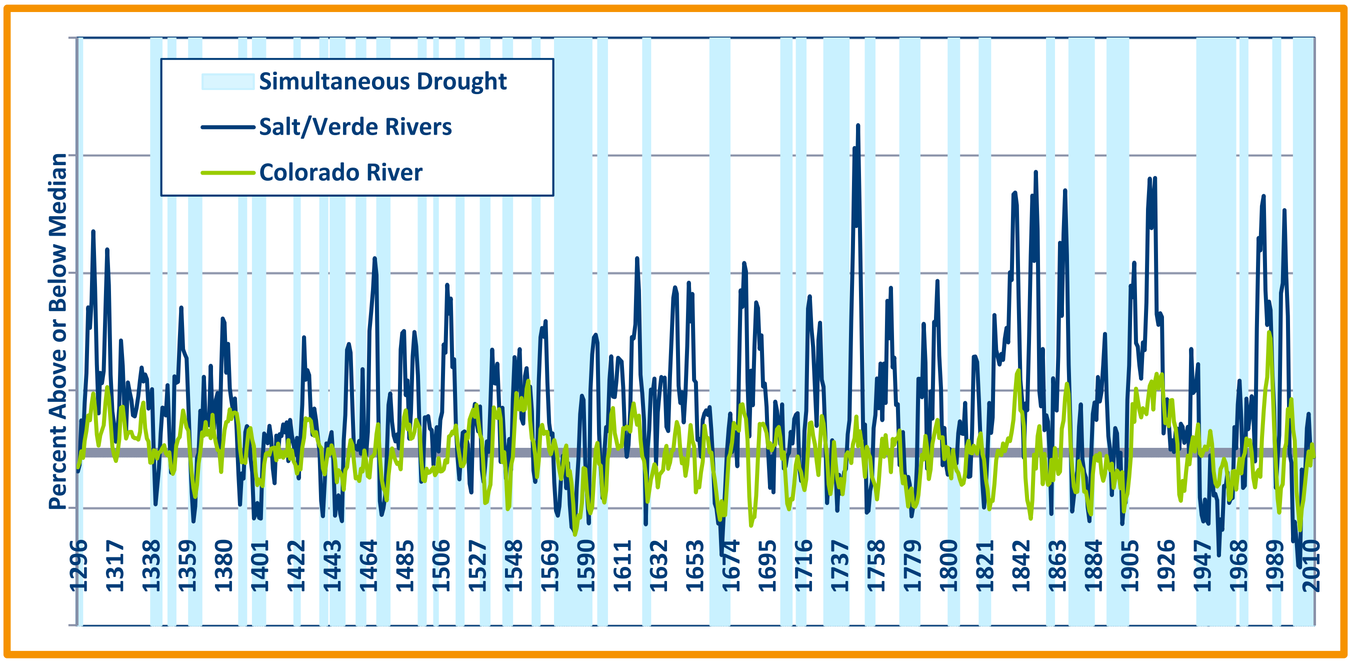

FIGURE 21. HISTORIC INFLOWS AND SIMULTANEOUS DROUGHT (SOURCE: UNITED STATES GEOLOGICAL SURVEY)

[12] While El Niño and La Niña tend to increase the likelihood of wetter and drier winter conditions in the desert Southwest, actual conditions may not always reflect this. During winter 2015 /2016, a very strong El Niño did not result in enhanced precipitation in the southwestern United States.

[13] Weiss, Jeremy L., Castro, Christopher L., and Overpeck, Jonathan T., 2009, "Distinguishing Pronounced Droughts in the Southwestern United States: Seasonality and Effects of Warmer Temperatures" Journal of Climate Vol. 22, No. 22, pp 5918, 1520-0442.

Reservoir systems are designed to level out the seasonal and annual variations. Dry cycles that extend beyond the system's capacity to store for that variation inevitably generate shortages. As previously noted, in the case of the Colorado River system, the current 20+ year drought has been exacerbated by overallocation of available resources, especially in the Lower Basin states of California, Arizona and Nevada. Despite the substantial storage capacity in Lake Mead and Lake Powell, the Bureau of Reclamation predicts prolonged shortage conditions in the Lower Basin within the next 5 years. In addition, the impacts of long-term droughts will likely be further exacerbated by changing climate conditions, resulting in replications of historic long-term droughts in background conditions that are hotter and drier than those experienced in the past. In fact, some researchers have created scenarios that indicate the possibility of significant declines in Lake Mead or Lake Powell that could impact hydroelectric production and even produce "dead pool" conditions in which stored water cannot be withdrawn from either reservoir.[14] While decisions concerning reservoir and river management are not within its control, Phoenix will continue to encourage system conservation efforts in which Colorado River users purposefully leave allocated water in Lake Mead to benefit the entire Colorado River system and other efforts that improve supply conditions. The City will also deploy creative long-term infrastructure projects to maintain its resiliency in the face of supply deficits (as further discussed in Chapter 4). On the Salt/Verde Rivers system, the lower capacity SRP reservoirs can be depleted more rapidly, but because SRP uses local groundwater as an offset when reservoirs are depleted, the SRP system is also capable of rapid recovery as occurred in 2004-2005 and 2018-2019.

Effects of Climate Change on the Watersheds

As previously noted, the specific impacts to water supplies from climate change are far more uncertain than impacts from cyclical drought as there is no reliable historic basis to serve as a benchmark. One key distinction between cyclical drought and climate change is the potential for the development of "new normal" conditions (i.e., a lower water supply baseline). Where cyclical drought conditions are typically followed by periods of full reservoir recovery, a relatively permanent change in long term climate conditions could prevent such a recovery. This shift could have profound implications for the volume and types of water supplies needed, for demand management strategies, and for future infrastructure capacity. In effect, many trend-based factors utilized for decades in managing water resources may no longer be valid as historic patterns of wet and dry cycles may be affected by climate change.

According to the 2018 National Climate Assessment, produced by a team of more than 300 experts guided by a 60-member Federal Advisory Committee, the southwestern United States is already experiencing the impacts of climate change. The region has heated up markedly in

[14] "The Future Hydrology of the Colorado River Basin," Center for Colorado River Studies, Quinney College of Natural Resources, Utah State University, August 31, 2020.

recent decades, and the period since 1950 has been hotter than any comparably long period in at least 600 years.[15]

Winter snowpack, which slowly melts and releases water in spring and summer when both natural ecosystems and people have the greatest needs for water, is key to the Southwest's hydrology and water supplies. Over the past 50 years across most of the Southwest, there has been less late-winter precipitation falling as snow, earlier snowmelt, and earlier arrival of most of the year's streamflow. Projections of further reduction of late-winter and spring snowpack and subsequent reductions in runoff and soil moisture, pose increased risks to the water supplies needed to maintain the Southwest's cities, agriculture, and ecosystems.

Temperature-driven reductions in snowpack are compounded by dust and soot accumulation on the surface of snowpack. This layer of dust and soot, transported by winds from lowland regions, increases the amount of the sun's energy absorbed by the snow. This leads to earlier snowmelt and evaporation – both of which have negative implications for water supply, alpine vegetation, and forests.

Projections of precipitation changes are less certain than those for temperature. Under a continuation of current rising emissions trends, winter and spring precipitation is consistently projected to decline for the southern part of the Southwest by 2100 as part of the general global precipitation reduction in subtropical areas. In the northern part of the region, projected winter and spring precipitation changes are smaller than natural variations. Summer and fall changes are also smaller than natural variations throughout the region. An increase in winter flood hazard risk in rivers is projected due to increases in flows of atmospheric moisture into California's coastal ranges and the Sierra Nevada. These "atmospheric rivers" have contributed to the largest floods in California history and can penetrate inland as far as Utah and New Mexico.

Future droughts are projected to be substantially hotter. On the Colorado River Basin, drought is projected to become more frequent, intense, and longer lasting than in the historical record. These drought conditions present a signficant challenge for regional management of water resources and natural hazards such as wildfire.

Colorado River Management

Projections of potentially lower runoff and more intense and lengthy drought conditions on the Colorado River Basin reveal some of the challenges of the 1922 Colorado River Basin Compact, which apportioned 7.5 million AF to the "Upper Basin" states of Colorado, New Mexico, Wyoming, Utah, and Arizona, and another 7.5 million AF to the "Lower Basin" states of California, Arizona, and Nevada.[16] The Compact's annual apportionment of 15 million AF –

[15] USGCRP, 2018: *Impacts, Risks, and Adaptation in the United States: Fourth National Climate Assessment, Volume II* [Reidmiller, D.R., C.W. Avery, D.R. Easterling, K.E. Kunkel, K.L.M. Lewis, T.K. Maycock, and B.C. Stewart (eds.)]. U.S. Global Change Research Program, Washington, DC, USA, 1515 pp. doi: 10.7930/NCA4.2018

[16] Although both an Upper Basin and Lower Basin state, very little of Arizona's supply comes from the Upper Basin apportionment compared to the Lower Basin (up to 0.5 million AF compared to 2.8 million AF, respectively).

along with Mexico's rights to 1.5 million AF - is higher than average historic flows within the Basin, a problem that will only be exacerbated by the effects of climate change. The result is a "structural deficit" in which Lake Mead is reduced by 9 million AF (or approximately 12 feet in elevation) each year. A structural deficit will exist until the total allocation is aligned with actual river flows, which are closer to 13 million AF.

After several years of sustained drought in the early 2000s drove Lake Powell levels to then-record lows, the Colorado River Basin States convened and negotiated the Interim Guidelines for Shortages and Coordinated Operations for Lake Powell and Lake Mead ("Interim Guidelines"), a conjunctive management strategy for Lake Powell and Lake Mead. Effective through 2026, the Decision and Order reduces Arizona's and Nevada's lower basin apportionments when Lake Mead falls below specified elevations indicating "shortage" in the Lower Basin beginning at elevation 1,075'. Mexico also agreed to reductions in deliveries at the same elevations (Table 4).

Lake Mead Elevation	Arizona Reduction	Nevada Reduction	Mexico Reduction
1075'	320,000 AF	13,000 AF	50,000 AF
1050'	400,000 AF	17,000 AF	70,000 AF
1025''	480,000 AF	20,000 AF	125,000 AF

TABLE 4. 2007 GUIDELINES SHORTAGE SHARING BY ARIZONA, NEVADA AND MEXICO

Whether the cause is the structural deficit, prolonged drought, climate change, or a combination of all three, both Lake Powell and Lake Mead have experienced significant declines in elevation since 2000. Although Lake Mead has not yet dropped below the shortage elevations described in the Interim Guidelines, the continued declines in storage in both Lake Mead and Lake Powell resulted in additional discussions about further reducing deliveries from Lake Mead in an effort to reduce the risk of reaching storage volumes that could constitute a "crash" of the Colorado River Basin system of storage reservoirs.

In 2019, the Basin States adopted respective Drought Contingency Plans that are designed to provide additional safeguards to the reservoir system until the Interim Guidelines are renegotiated for 2027. The Lower Basin Drought Contingency Plan ("LBDCP") provides for larger and more frequent reductions in deliveries to Arizona and Nevada if Lake Mead elevations drop below 1,075' (Table 5). The impact to Phoenix could mean a complete loss in deliveries of its Non-Indian Agriculture priority water and perhaps a small reduction in its Municipal & Industrial priority and Indian priority water. Arizona adopted an Implementation Plan that provides mitigation of the loss of some of these volumes through 2025.

Lake Mead Elevation	AZ Reduction	NV Reduction	CA Reduction	USBR Reduction	Mexico Reduction
1075–1090'	192,000 AF	8,000 AF	0	100,000 AF	0
1050-1075'	512,000 AF	21,000 AF	0	100,000 AF	50,000 AF
1045-1050'	592,000 AF	25,000 AF	0	100,000 AF	70,000 AF
1040-1045'	640,000 AF	27,000 AF	200,000 AF	100,000 AF	70,000 AF
1035-1040'	640,000 AF	27,000 AF	250,000 AF	100,000 AF	70,000 AF
1030-1035'	640,000 AF	27,000 AF	300,000 AF	100,000 AF	70,000 AF
1025-1030'	640,000 AF	27,000 AF	350,000 AF	100,000 AF	70,000 AF
<1025'	720,000 AF	30,000 AF	350,000 AF	100,000 AF	125,000 AF

TABLE 5. LOWER BASIN DCP SHORTAGE SHARING

While the LBDCP is intended to mitigate the risk of Lake Mead falling precipitously, the LBDCP does not eliminate that risk. The Colorado River remains overallocated and storage volumes in Lakes Powell and Mead are heavily dependent on snowpack, even as the climate warms and snowpack melt patterns change. As will be discussed in Chapter 5, changes to the resiliency of Phoenix's Colorado River supplies will require the City to take additional proactive measures to ensure safe and reliable water deliveries to its customers, regardless of conditions on the Colorado River.

Forest Management

Forest management's role in preserving winter snowpack and water quality will likely play a greater role as climate change triggers hotter temperatures in the southwestern United States. Inadequate forest management of the Mogollon Rim forests, which encompasses parts of the

Salt and Verde Rivers watershed, has led to increasingly larger and hotter forest fires compared to what would have occurred in the forest's natural state. The result exposes snow to excessive sunlight, causing it to melt more quickly. The associated runoff is laden with ash and debris, which reduces reservoir capacity and negatively affects water quality. By contrast, healthy forests have smaller, less intense forest fires, which protects winter snowpack, reduces the rate of snowmelt, and reduces water quality concerns.

In 2015, the City began a partnership with the Northern Arizona Forest Fund (NAFF), which was developed by the National Forest Foundation in partnership with SRP. Through the NAFF, Phoenix supports the implementation of numerous forest restoration and watershed health projects on National Forest lands in the Salt and Verde River Watersheds. Specifically, the NAFF has implemented projects on the Apache-Sitgreaves, Coconino, Kaibab, Prescott, and Tonto National Forests that reduce the risk of catastrophic wildfire as well as decrease erosion and sedimentation into streams, rivers, and important reservoirs.

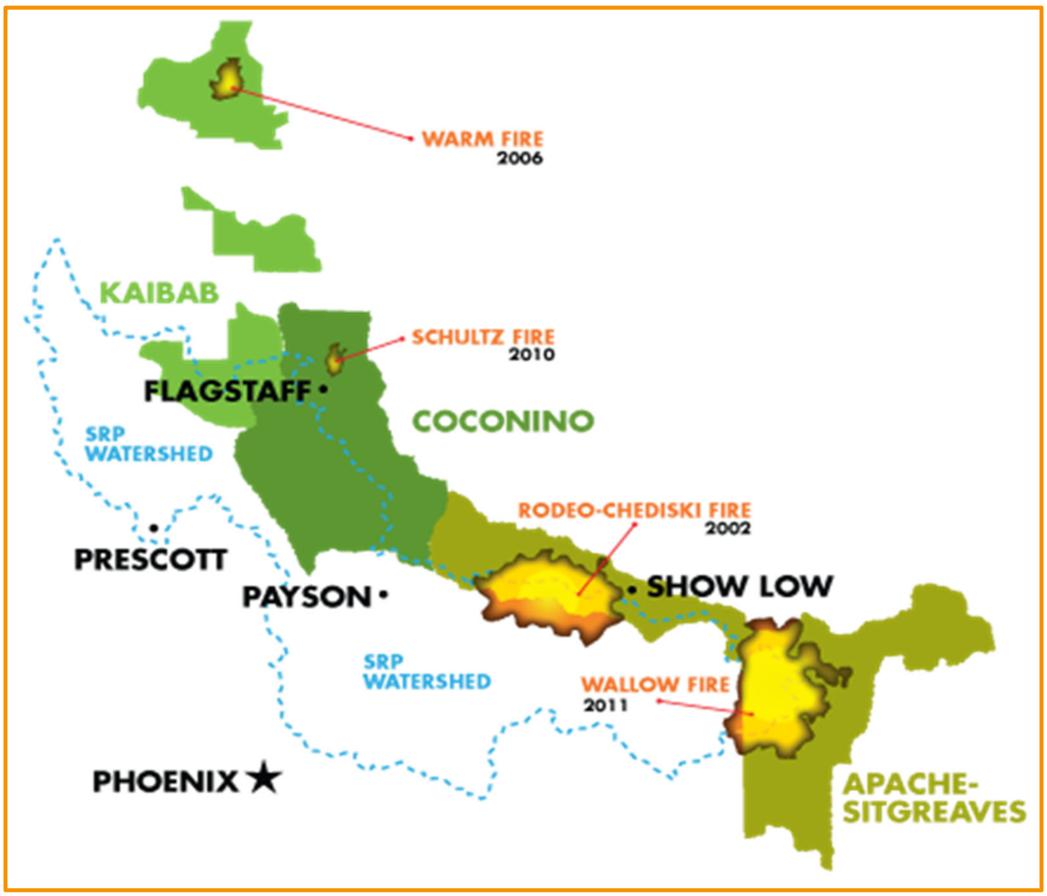

FIGURE 22. RECENT LARGE WILDFIRES ON THE MOGOLLON RIM (SOURCE: SALT RIVER PROJECT)

In 2019, the City entered into a similar agreement with The Nature Conservancy ("TNC") to fund forest restoration and conservation to improve water quality in the Verde Watershed. TNC collaborates with water users in the Verde Valley to conserve water and make uses more efficient. In addition, TNC will pilot the use of new technologies to make forest thinning more efficient and timelier.

2.4 Groundwater: Assured Water Supply, Wells, and Hydrogeology

Assured Water Supply Groundwater Credits

Groundwater may be pumped and used by Phoenix pursuant to Arizona law, but with strict controls. In 1995, ADWR adopted the Assured and Adequate Water Supply Rules as part of the Groundwater Code, which are designed to sustain the state's economic health by preserving groundwater resources and promoting long-term water supply planning. Applicants must now demonstrate the use of renewable water supplies, rather than groundwater, in amounts sufficient to meet most of the demand of development for 100 years. Renewable supplies include surface water such as Salt, Verde, and Colorado River water, and wastewater effluent (i.e., reclaimed water). If the applicant proposes to use groundwater as part of its assured water supply, a hydrologic study is required for the affected area. Groundwater is considered physically available as part of an assured water supply only if certain depth-to-static water level standards, measured in feet below land surface, are not exceeded in 100 years.

The Assured Water Supply designation for Phoenix established groundwater allowances credits that may be used by the City at any time. Phoenix currently holds more than 3 million AF of these credits for use over a 100-year period. These credits are intended mostly to provide relief if surface water shortages occur. Additional credits are accrued by the City each year to reflect the incidental recharge of local aquifers that results from service area water usage.

Wells – Past and Present

Over the years, the City has developed or acquired more than 200 groundwater production wells for water supply. Today, however, most of these wells have been removed from service due to age, reduced efficiency and/or degraded water quality due to groundwater contamination (see the "Water Quality section that follows). In addition, after 1980, the City made a policy decision to primarily rely on surface water supplies instead of groundwater; so, as wells were removed from service, they were not replaced. The City currently has 22 active wells for water production, which can generate approximately 32 million gallons of water per day (MGD), equivalent to about 35,500 AF per year, if each of these wells run continuously all the time. In practice, however, wells typically are operated approximately 65 percent of the time (expressed as pump duty) because of operational and maintenance needs. Based on this typical pump duty, actual groundwater production capacity from the existing wellfield is approximately 23,000 AF per year, equivalent to 20.6 MGD.

Although these wells make up a small portion of Phoenix's total water production, they are an important supplemental source of water during daily and seasonal peak water usage in the areas of the City served by the Lake Pleasant WTP and Union Hills WTP. Groundwater pumped by production wells has averaged approximately 7,000 AF annually over the past decade, which is a small fraction compared to the City's surface water supplies. In addition to production wells, several City facilities are wholly or partially served by their own dedicated wells, most notably the Cave Creek Park and Golf Course, Encanto Park and Golf Course, and Cactus Park.

Due to water quality issues throughout much of the central parts of the City, many City wells currently pump groundwater from the northeast aquifer, which is bound roughly by Bell Road, Scottsdale Road, and 7th Street. This regional aquifer is used by several agricultural users and municipal water providers. Major efforts have been underway to model this aquifer, to collaborate with other entities drawing from the aquifer, and to begin developing mechanisms to replenish depleted groundwater supplies.

The City is further developing its capability to serve off-project areas with groundwater supply as a back-up water source, in case of shortages on the Colorado River system from drought, infrastructure reliability, and other issues. Both water supply production wells and ASR wells are being drilled and constructed for this purpose in a multi-year, phased approach. The City has concentrated its construction of the ASR wells in the northeast aquifer in a concerted effort to recharge this important aquifer. Most of these wells will be operational by 2024.

Given the long lead time and costs associated with wellfield drilling and operation, in 2018, the City signed a 40-year agreement with SRP giving the City priority access to SRP’s vast well capacity. This agreement leverages Phoenix’s ongoing storage of its Colorado River water in SRP’s reservoir district with SRP’s robust well capacity and water delivery infrastructure within the City. The agreement ensures reliable water deliveries during extreme drought and shortage conditions on the Colorado River when needed. Pursuant to the agreement, Phoenix can recover up to 20,000 AF per year of long-term storage credits (“LTSCs”) from SRP's wells located within the Salt River Reservoir District. Once recovered, these LTSCs can be used anywhere within the City’s water service area. Phoenix paid a one-time fee of $12.3 million to reserve this pumping capacity from SRP and will pay an additional fee based on the volume pumped from SRP wells.

In order to ensure groundwater stored and recovered in the central and southern portion of Phoenix can be delivered during shortage to areas of the City that rely upon Colorado River water, the City is constructing an ambitious infrastructure project to pump water north. Large transmission mains and associated pump stations will ensure seamless delivery of water supplies to all portions of the City under even the most challenging supply restrictions. While these actions collectively improved the City’s access to its groundwater reserves, additional challenges exist with groundwater quality (in central Phoenix) and groundwater table declines (in north Phoenix).

2.5 Aquifer Recharge, Long Term Storage Credits and Recovery

ADWR Recharge Program

In 1986, and then later refined in 1994, the Arizona State Legislature established an aquifer recharge program administered by ADWR. The goal of the program is to encourage the storage of renewable supplies in the groundwater aquifers and to recover that supply at a later time for the storing entity’s use.

State law identifies two types of permitted facilities to store renewable supplies: Underground Storage Facilities (USFs) and Groundwater Savings Facilities (GSFs). USFs may either be a constructed facility that uses some type of constructed device such as a percolation basin, ASR well, or an injection well, to store water in the aquifer; or a USF can be a managed facility, which stores water by discharging into a natural waterway where the water percolates downward into the aquifer without the assistance of a constructed device.[17] GSFs are technically not facilities *per se*, but they allow the delivery of a renewable supply to a recipient who uses this water instead of pumping groundwater.

Once an entity has been permitted to store or recharge water at a recharge facility and such water is stored for more than a year, one long term storage credit (LTSC) may be earned[18] for each AF of water stored, less transmission losses, evaporative losses, and a "cut to the aquifer" that is deducted from all renewable supplies stored except reclaimed water.[19] Once earned, for the purposes of ADWR accounting, LTSCs maintain the legal character of the original source water (i.e. Colorado River water stored and then recovered has the same legal characteristics as Colorado River water).

Long Term Storage Credit Balances and Current Uses

The City maintains permits to recharge the groundwater aquifer with Colorado River water, NCS, and reclaimed water supplies that are not needed to meet current demands. The water stored may be pumped or "recovered" in the future when additional supplies are needed for operational flexibility to meet growth and/or drought related demands. Through 2019, the City is estimated to have stored more than 287,000 AF of Colorado River supplies, more than 125,000 AF of reclaimed water or effluent, and almost 21,000 AF of NCS supplies (Figure 23) through the projects described below. Water received from SRP for the RID three-way exchange is legally considered effluent.

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[17] An ASR well is a single well used for both the storage of water into the aquifer and then recovery of stored water at a later date at the same location. Injection wells store water using a similar method, but recovery is conducted at a different location.

[18] Credits are earned when recovery is consistent with the management plan and the goals of the AMA (A.R.S. § 45-834.01), and when recovery will occur inside or within three miles of the service area of a city, town, private water company or irrigation district, that city, town, private water company or irrigation district is the person recovering the water or has given consent to the recovery. A.R.S. § 45-834.01.

[19] The cut to the aquifer is deducted as five percent (5%) of the amount stored at a USF or GSF, unless the stored water was imported into the AMA through the efforts of the storer (0 cut); stored outside an AMA and imported into a groundwater basin through the efforts of the storer (0 cut); effluent stored at a constructed USF (0 cut); or effluent stored at a managed USF permitted in 2019 or later (50% cut).

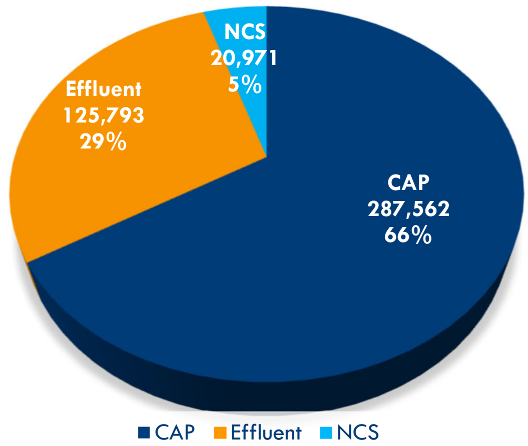


FIGURE 23. ESTIMATED LONG TERM STORAGE CREDITS EARNED THROUGH 2019 IN ACRE-FEET

Storage and Recovery Facilities in the Phoenix Area

GRANITE REEF UNDERGROUND STORAGE PROJECT (GRUSP)

GRUSP is a constructed, open basin facility maintained by SRP on land within the Salt River Pima-Maricopa Indian Community. The facility is owned by SRP as well as the Cities of Chandler, Mesa, Phoenix, Scottsdale, Tempe, and the Town of Gilbert. Phoenix owns 25.755% of the capacity at GRUSP. Phoenix has stored both Colorado River and NCS water supplies at GRUSP. As of 2019, Phoenix has generated approximately 50,966 AF of LTSCs in GRUSP.

SRP GSF

Phoenix provides Colorado River water to SRP to replace groundwater that SRP would have otherwise pumped (this is also referred to as "in-lieu" recharge). Phoenix receives credits for the water that remains in the aquifer (less the minimal "cut to the aquifer" described previously). As of 2019, Phoenix has generated approximately 106,472 AF of LTSCs in SRP's GSF.

RID GSF

This "in-lieu" recharge project allows Phoenix to accrue credits for groundwater that would have otherwise been pumped if not for the reclaimed water provided to RID from the 23rd Avenue WWTP. Phoenix earns LTSCs through the GSF only for reclaimed water deliveries to RID in excess of what is provided as part of the "RID Three-Way Exchange" described earlier in this chapter. If the exchange is not executed in any given year, Phoenix can elect to continue to provide RID wastewater effluent within the RID GSF to earn LTSCs for up to 30,000 AF annually based on the reclaimed water delivery to RID. Using this method, Phoenix has earned approximately 125,792 AF of LTSCs at the RID GSF through 2019.

NORTHEAST AQUIFER STORAGE AND RECOVERY WELLS

As described above, Phoenix's and other's reliance on the northeast aquifer for groundwater supplies requires mechanisms to better manage the aquifer. Beginning in 2011, Phoenix constructed a series of ASR wells that stores treated Colorado River water in the most productive strata of the aquifer. Phoenix is currently permitted to recharge up to 5,845 AF per year of CAP water in three existing, operating ASR wells. Additional ASR wells are being installed in this area to replenish the aquifer and store water underground for future use. These wells are being drilled and constructed in a multi-year, phased approach. The majority of these wells will be online by 2024 or sooner.

DEER VALLEY WTP AQUIFER STORAGE AND RECOVERY WELL

An ASR well was drilled and constructed at the Deer Valley WTP in 2015. In August 2017, the City received an USF permit from ADWR to operate this well for aquifer storage over a 20-year time period. This project allows the City to store up to 3,000 AF of Colorado River or NCS water per year underground at the campus of the Deer Valley WTP using this well.

Storage and Recovery in the Tucson Area

In 2014, Phoenix entered into parallel agreements with the City of Tucson ("Tucson Water") and Metropolitan Domestic Water Improvement District ("Metro") to store part of Phoenix's Colorado River entitlement at recharge facilities in the Tucson Area. Phoenix has been permitted by ADWR to store up to 50,000 AF per year of its supplies at Tucson Water's Southern Avra Valley Storage and Recovery Project ("SAVSARP"), a constructed open-basin recharge facility, upon mutual agreement with Tucson Water. Similarly, Phoenix has been permitted to store up to 4,000 AF of water at Metro Water's Avra Valley Recharge Project ("AVRP"), which is also a constructed open-basin facility. Phoenix accrues LTSCs for the water stored in the Tucson area. Through 2019, the City has earned approximately 102,715 AF in LTSCs at SAVSARP and 11,431 AF of LTSCs at AVRP.

FIGURE 24. SOUTHERN AVRA VALLEY STORAGE AND RECOVERY PROJECT (SOURCE: TUCSON WATER)

When Colorado River deliveries are reduced because of shortage conditions, Phoenix will recover the LTSCs earned at each respective facility at wells located in Tucson and the water will be delivered to Tucson Water's and/or Metro Water's distribution system(s). Tucson Water and/or Metro Water would, in turn, direct delivery of a like amount of their Colorado River supplies to Phoenix water treatment plants through the CAP.

Use of Recovered Credits

Most of the LTSCs earned through recharge are created for the purpose of "banking" unused supplies that can be recovered when Colorado River or Salt and Verde Rivers supplies are in shortage. However, due to infrastructure constraints and limited supply availability, a small quantity of effluent credits is regularly recovered using on-site wells to meet the demands of two facilities within the City: the Rio Salado Restoration Project, which stretches from 28th Street to 19th Avenue within the Salt River bed and provides desert habitat, recreational and educational facilities, and the Laveen Area Conveyance Channel, a flood mitigation project in the southwestern part of Phoenix.

2.6 Reclaimed Water

Approximately 40 percent of water delivered to all Phoenix customers ends up at one of the City's two operational wastewater treatment plants and is treated for other uses. Most of this water is used to meet non-potable water demands in the Valley

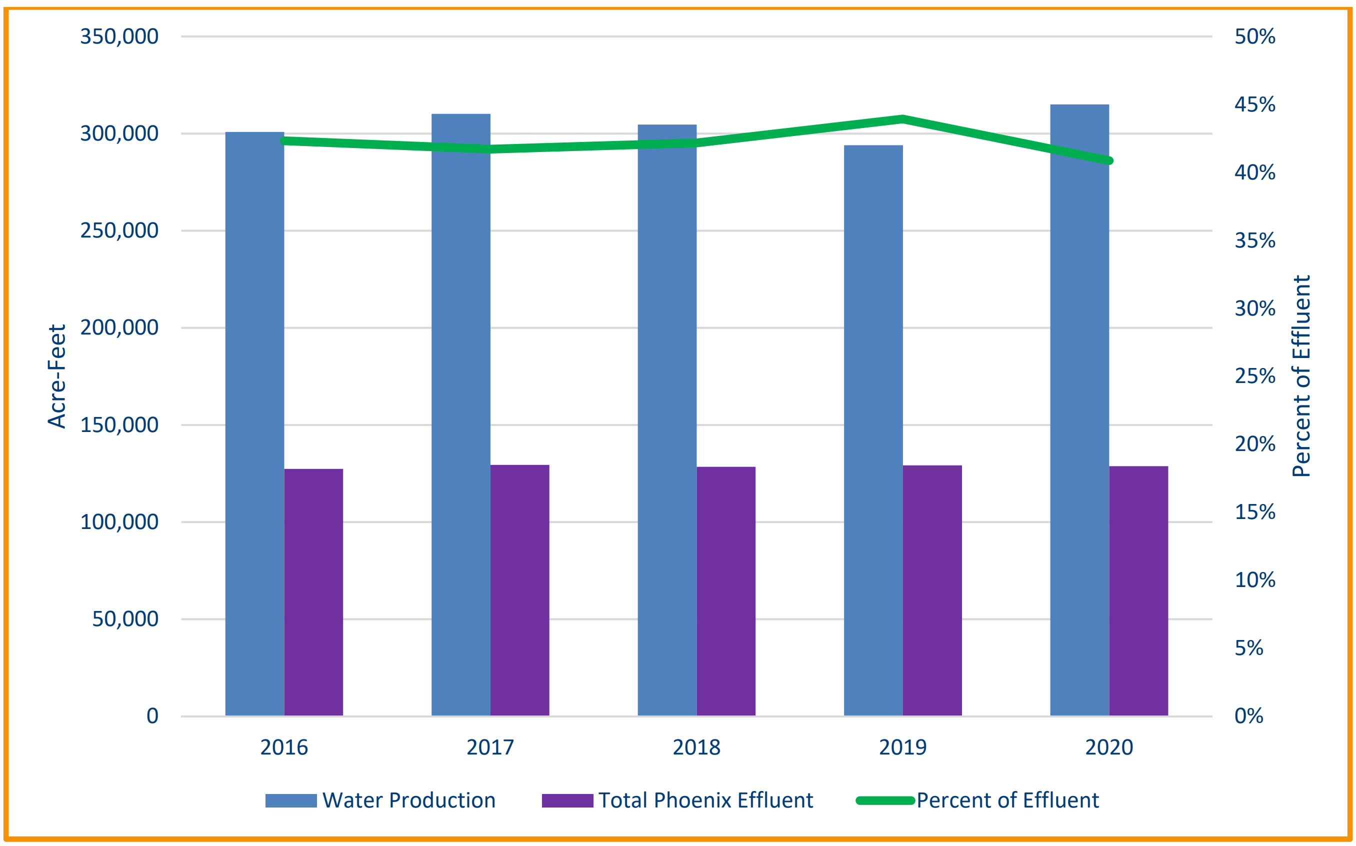


FIGURE 25. RATIO OF PHOENIX EFFLUENT TO WATER PRODUCED: 2010 - 2015

Treatment

Phoenix has two operational wastewater treatment facilities: the 91st Avenue Wastewater Treatment Plant (91st Avenue WWTP), and the 23rd Avenue Wastewater Treatment Plant (23rd Avenue WWTP). The City owns an additional reclamation facility, the Cave Creek Water Reclamation Plant (Cave Creek WRP), that is currently not in operation. The largest plant is the 91st Avenue WWTP. The original 5 MGD plant was built in 1958 and was later replaced with a 45 MGD plant. In 1979, the Sub-Regional Operating Group (SROG) was formed between the Cities of Glendale, Mesa, Phoenix, Scottsdale, Tempe, and the Towns of Gilbert and Youngtown to jointly own and operate the plant and associated sewer transportation facilities. The Town of Gilbert sold its system capacity to the City of Mesa in 1981 and the Town of Youngtown sold its capacity to Phoenix in 1995. The plant is currently rated at a capacity of 230 MGD. Phoenix's share of the capacity is 112.8 MGD.

Phoenix oversees the operation of the 91st Avenue WWTP and the two large wastewater collection interceptors - the Salt River Outfall Sewer (SRO) and the Southern Avenue Interceptor (SAI). The SRO is located primarily north of the Salt River along the Lower Buckeye Road alignment. This sewer conveys flows from the cities of Phoenix, Scottsdale, Mesa, and Tempe to the plant. At 23rd Avenue and Lower Buckeye Road, there is a diversion structure that diverts a portion of the City of Phoenix flows to the City of Phoenix 23rd Avenue WWTP. The remaining flows are conveyed to the 91st Avenue WWTP. The SAI is located primarily south of the Salt River along the Southern Avenue alignment. This sewer conveys flows from Phoenix, Mesa, and Tempe to the 91st Avenue WWTP. Additionally, there is a third major sewer interceptor referred to as the 99th Avenue Interceptor that is jointly owned by Phoenix and Glendale.

The 23rd Avenue plant was originally built in 1938. It was expanded in the late 1990s and currently has a treatment capacity of 63 MGD. The plant site has been master-planned to accommodate up to 120 MGD. A portion of the City of Phoenix sewer collection system flows to the 23rd Avenue WWTP by gravity. Additionally, flow can be diverted from the SRO through a pump station to the 23rd Avenue WWTP.

The Cave Creek WRP is master planned to accommodate up to 32 MGD and was constructed in 1998 with a capacity of 8 MGD. The plant was designed to collect wastewater flows from new development north of the CAP Canal. As development occurred in the area, flows into the plant averaged 3.77 MGD. The sharp recession in the late 2000s curtailed further new development and made operating the plant cost prohibitive. In 2009, the plant was temporarily shuttered, and all wastewater flows were diverted to the 91st Ave WWTP. The plant is scheduled to resume operations in 2024/2025.

Reclaimed Water System

The Cave Creek WRP is connected to a reclaimed water system designed to provide non-potable water for turf and landscape watering purposes. Currently, 13 facilities are connected to the system. While the Cave Creek WRP is offline, untreated Colorado River water or potable water from the Union Hills WTP can be delivered to the Cave Creek WRP reclaimed water reservoir to serve customers. Once the WRP is back online, untreated Colorado River water will be commingled with reclaimed supplies to meet customer demands. The commingling of untreated Colorado River Water will help with managing summer peak demands and with mitigating high salinity levels of reclaimed supplies, which is challenging for managing turf and soil quality.

Reclaimed Water Delivery Agreements and Obligations

Large quantities of effluent produced by the 91st Avenue and 23rd Avenue WWTPs are committed to large effluent users through long term agreements with the City and other partners. These agreements are described below and conceptually shown in Figure 26.

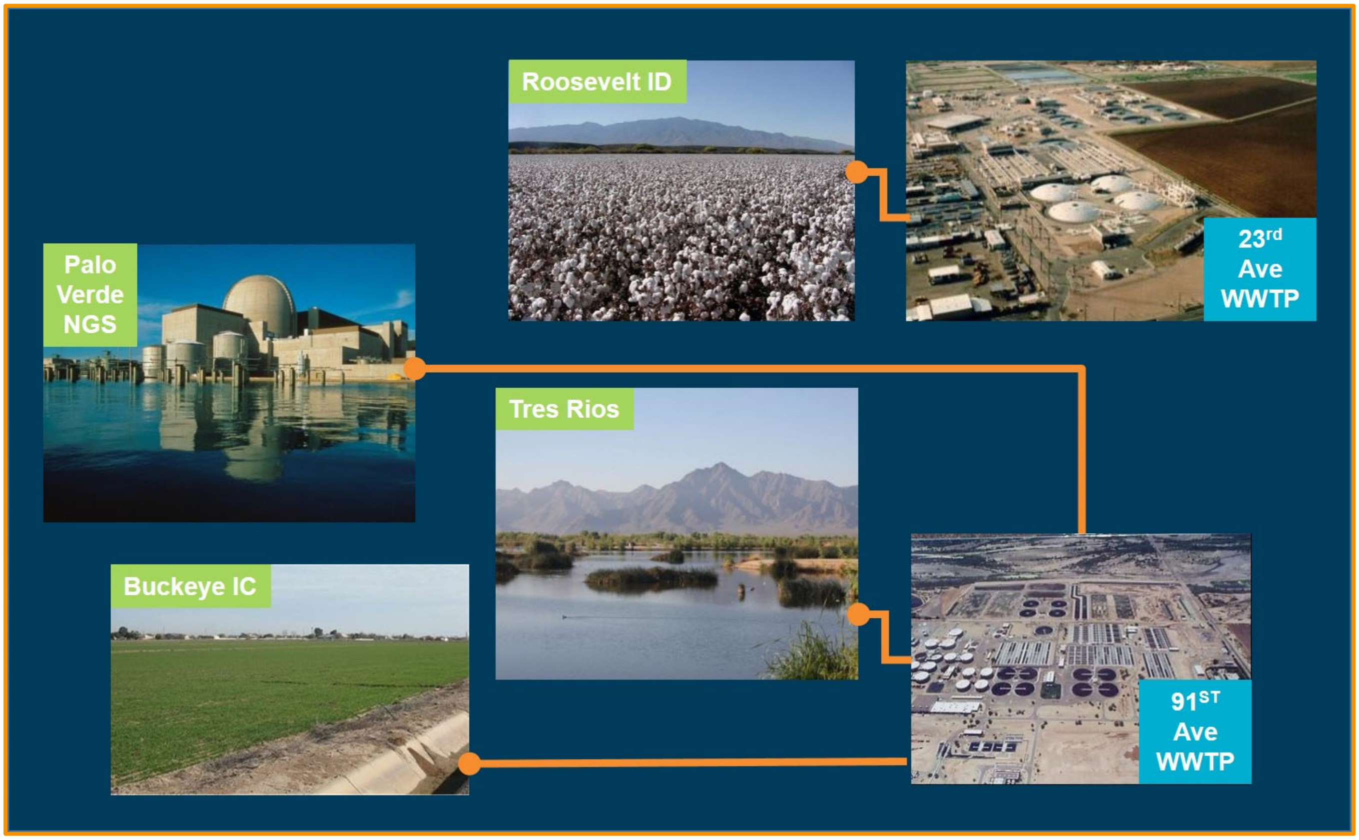


FIGURE 26. RECLAIMED WATER DELIVERIES OUTSIDE THE SERVICE AREA (SOURCES: UNIVERSITY OF ARIZONA, ARIZONA PUBLIC SERVICE)

<u>BUCKEYE IRRIGATION COMPANY</u>

Since 1971, the SROG cities have had a contract with the Buckeye Water Conservation and Drainage District and the Buckeye Irrigation Company (collectively BIC) that gives BIC the option to take effluent released into the Salt River downstream from the 91st Avenue WWTP for delivery through a canal system to irrigate agricultural lands within BIC. The current agreement, effective in 1994, makes BIC's obligations and requirements contingent on the amount of effluent annually available from the plant. If less than 20,000 AF of effluent is available to BIC annually, BIC can take all or part of what is available that year. If more than 20,000 AF per year is available to BIC, BIC must take at least 20,000 AF annually, but BIC cannot take more than 40,000 AF in any given year. The agreement has four option periods or time periods in which BIC must specify the amount of effluent needed during that option period. One year prior to each option period, SROG cities are required to notify BIC of the amount of effluent available. BIC exercised its third option in 2020 and agreed to accept 20,000 AF of effluent annually through calendar year 2025. If the SROG Cities make effluent available to BIC after 2025 and BIC elects to exercise the fourth option period, then the agreement would extend to 2030.

There are also seasonal delivery requirements in the contract. The contract specifies that BIC must receive 5 percent per month of its annual delivery from September to March, 10 percent each for April and May, and 15 percent each for June, July, and August.

PALO VERDE NUCLEAR GENERATING STATION

Palo Verde Nuclear Generating Station (PVNGS), located approximately 50 miles west of Phoenix, came online in 1986. The facility is owned by Arizona Public Service, Salt River Project, El Paso Electric Company, Southern California Edison, PNM Resources, Southern California Public Power Authority, and the Los Angeles Department of Water and Power. There are three separate units at the facility, and they operate independently of one another. All three units are wet cooled. PVNGS is the only nuclear power facility in the world not located next to an above ground body of water. Instead, effluent from the 91st Avenue WWTP is used by PVNGS for cooling water needs, and it is sent directly from the treatment plant to an 80-acre reservoir system at the facility by way of a dedicated pipeline.

The original agreement between the SROG Cities, the Town of Youngtown, APS and SRP was executed in 1973 and provided up to 105,000 AF annually for PVNGS. This agreement was set to expire in 2027. However, in 2008, APS, the operating agent for the facility, filed for license extensions with the United States Nuclear Regulatory Commission through 2047 for all three operating units. As a result, PVNGS owners sought to secure an effluent supply through 2050, and a new agreement, which replaced the existing one, was executed between the SROG cities and PVNGS ownership in 2010 and expires in 2050.

In the new agreement, SROG cities agree to deliver up to 80,000 AF annually through the dedicated pipeline, with up to 7,000 AF delivered monthly from January through April and October through December, and up to 8,000 AF to be delivered monthly from May through September. Other provisions include, but are not limited to:

- PVNGS owners have the right to an additional 8,000 AF if “certain conditions change substantially” at the PVNGS and if the effluent is reasonably available;
- If cooling tower discharge exceeds 75,000 AF per year due to the effluent not meeting minimum quality standards, SROG cities must provide PVNGS up to 10 percent additional effluent free of charge;
- The PVNGS owners have the option to extend the agreement through 2070; and

- PVNGS Priority is higher than any other preexisting commitments *except* BIC (30,000 AF), Arizona Game and Fish Fire Department (7,300 AF) and the United States Water Conservation Lab (1,200 AF).

ROOSEVELT IRRIGATION DISTRICT – WATER EXCHANGE AND GROUNDWATER SAVINGS FACILITY

The "three-way" exchange between Phoenix, the SRPMIC and SRP is described in detail above. For the exchange, Phoenix delivers up to 30,000 AF per year of treated wastewater from the 23rd Avenue WWTP to the RID, which delivers the water to farms. RID, in turn, provides a like amount of groundwater to the SRP canal system through its own wells or wells leased from SRP. SRP then credits Phoenix up to 20,000 AF per year and SRPMIC up to 10,000 AF per year of water to be used anywhere within their respective service areas.

TRES RIOS WETLANDS

In 1990, the Arizona Department of Environmental Quality set stringent water quality standards for wastewater discharges into Arizona waterways, which affected discharges from the 91st Avenue WWTP into the Salt River. In order to meet the new discharge standards cost-effectively, particularly for removing nitrogen, the City began construction on the Tres Rios Wetlands demonstration project in 1995. Through a partnership between the cities of Phoenix, Tempe, Mesa, Scottsdale, Glendale, and the Bureau of Reclamation, the Tres Rios Demonstration Project was constructed as three operational wetlands - the Hayfield site (6 acres), the Cobble site (4 acres), and the Research Cell (1 acre) - in a one-mile corridor downstream from the treatment plant. The flow of water from the demonstration project sustained riparian habitat and proved successful in meeting treatment requirements that were needed. This green infrastructure serves two objectives: It replaced up to $250 million dollars of additional mechanical treatment capacity that would have been required at the 91st Avenue WWTP, and it made water available for wetlands and wildlife habitat. These wetlands provide food, shelter and water to migratory birds along the Pacific Flyway and contribute to a healthier riparian environment downstream in the Salt and Gila Rivers.

In 2000, the U.S. Army Corps of Engineers received approval from Congress for the Tres Rios Ecosystem Restoration and Flood Control Project, a 7-mile long, 1500-acre section of the Salt and Gila Rivers in southwestern Phoenix located west of the 91st Avenue WWTP. The expanded wetlands project, which is a partnership with SROG, the U.S. Bureau of Reclamation, and the U.S. Army Corps of Engineers, consists of a flood protection levee, effluent pump station, emergent wetlands, and riparian corridors and open water marsh areas to replace existing non-native salt cedar in the river. The wetlands consumptively use approximately 19,500-23,000 AF per year of wastewater effluent from the 91st Ave WWTP.

CHAPTER 3 – WATER DEMAND TRENDS AND IMPLICATIONS

A solid understanding of water demand characteristics and trends plays a fundamental part in assessing water supply and infrastructure needs. Phoenix's water use profile reflects the City's strong economy and enhanced quality of life, and the types of technology and landscapes that are required to maintain them. In the past, economic and population growth typically led to increases in water use, both on a per-person basis and an aggregate basis. Today, urban water demand has fallen dramatically as measured by the metric, gallons per capita per day (GPCD). Increases in water demand have largely decoupled from population and economic activity as more efficient devices and landscapes have revolutionized the way that Phoenicians interact with their environment.

This chapter characterizes current demand in Phoenix and examines how various trends and policies could affect the City's demands in the next half century. Substantive changes may occur over a relatively short period due to technological advances, consumer preference, and demographic shifts. The City recognizes the need to anticipate changes in water demand trends and influence them to meet water management goals.

3.1 Current Profile

Population and Demand

The population in Phoenix grew rapidly from the Second World War until the severe recession that began around 2007. This downturn was felt throughout the nation, but the recession impacted the Phoenix metropolitan area especially hard. 1587520Local economy and service area growth has been recovering slowly and steadily over the past decade or so. In fact, due to continuing growth, Phoenix overtook Philadelphia as the nation's fifth-largest city in 2017.

For many years, increasing water demand was highly correlated with population growth as additional people required additional water. Employment growth often brings increased water use, especially in sectors like food processing, manufacturing, health care, and hospitality, so it has played an important role in determining additional water demands. However, since the 1990s, the relationship between population and employment growth, and water demand, has steadily weakened. For example, the City's annual water production has been relatively flat since 1996, even though the City's population grew more than 25 percent over that same time. In fact, since the City's water production peaked in 2002, total demand has declined by more than 15 percent, while the service area population has increased by 20 percent through 2019.

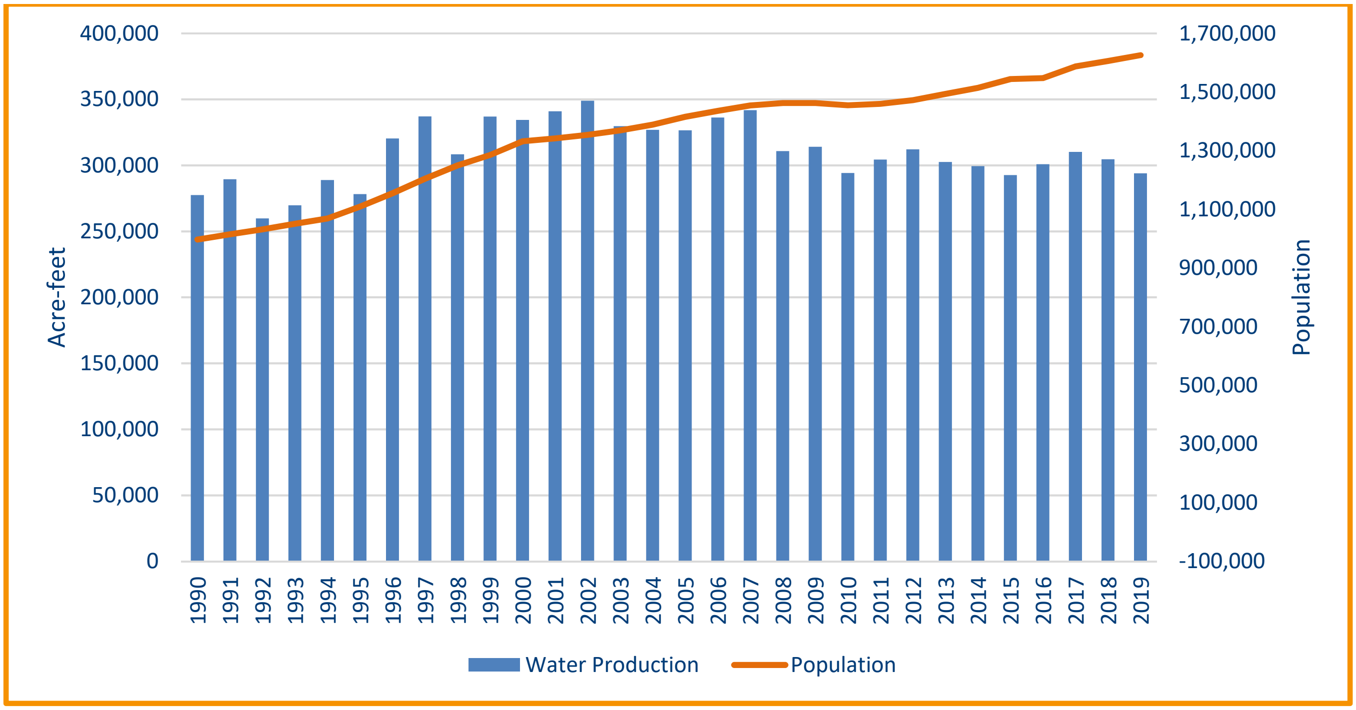
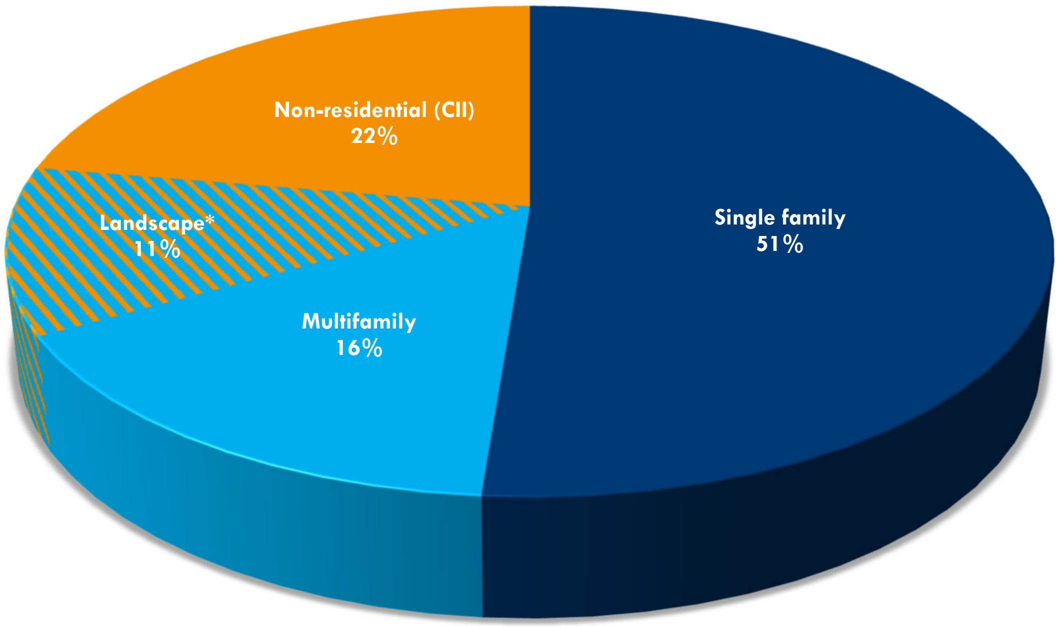


FIGURE 27. PHOENIX WATER DEMAND AND POPULATION GROWTH, 1990-2019

The weakened relationship between population growth and water demand is evident when measuring water consumption in terms of per-capita or per person water demand, which has declined by nearly 28 percent in the last 16 years (Figure 27). Contributing causes, which are described in more detail below, include: federal, state, and local plumbing fixture standards as well as appliance manufacturing requirements for new and replacement devices; increased adoption of desert landscaping in both new and existing homes and businesses; fewer new pools in housing developments built after 2000; and an increased desire on the part of homeowners and businesses to install devices, equipment, and irrigation systems that reduce water and energy costs while protecting the environment.

Water Use by Sector

The City's water use for its approximately 440,000 accounts in 2020 can be broken down into three major sectors: single-family residences; multifamily residential developments; and non-residential water uses, which are commonly referred to as the "commercial, industrial, and institutional" (CII) sector (see Figure 28). Dedicated landscape water meters are commonly used in both the CII and multifamily water use sectors and are shown separately in Figure 28. However, for the sake of simplicity, landscape water use will be accounted as part of the CII sector. While single-family residences make up about 88 percent of all accounts, they only account for about half of the City's potable water use. Another 16 percent of water use is attributable to domestic use by multifamily developments of various types (apartments, condominiums, townhouses, etc.), while 33 percent of water use is by the CII sector (including all landscape meters). The proportions of water use of these major sectors has been remarkably consistent over the past 30 years, especially because water efficiency gains by residential sectors have been so significant. The CII sector is very fragmented, diverse, and includes a wide range of water uses such as retail establishments, office buildings, industrial warehouses and processing facilities, resorts, hotels and motels, commercial laundries, schools, institutions, and many other entities.



*Dedicated landscape meters are found at both CII and multifamily facilities. This is the aggregated total for both water use sectors.

FIGURE 28. WATER USE BY SECTOR

RESIDENTIAL WATER USE

Residential water demand was 171,913 AF in 2019, resulting in a residential use of 94 gallons per person per day. However, looking at the City's total residential water use does not reveal the diversity in household water use. Phoenix is a relatively new city with much of its growth occurring after World War II. Housing stock is diverse with significant construction spanning many decades. The types of indoor fixtures and appliances are generally the same whether the homes are old or new, but often the age and efficiency levels of the devices will vary considerably depending on a number of factors: Newer homes have newer appliances and fixtures, but homes in the oldest parts of the City are being renovated, resulting in the installation of new, efficient toilets and clothes washers.

The types of outdoor landscaping associated with homes can vary greatly based on the age of home and geographic location. Older homes that have not been recently landscaped are less apt to have native or desert-adapted landscaping plants and trees with gravel and rock, which is much more prevalent in newer homes, and are more likely to have grass and more water-intensive, non-native plants. However, mostly desert or partially-desert landscapes are now the norm in virtually all parts of the City, including old and new areas. Homes built prior to 2000 also more frequently have pools than newer homes. From the mid-1960s to 2000, more than 40 percent of homes had swimming pools installed (Figure 32). While the types of landscapes and devices found in homes are key factors that determine single-family residence water use, there are other important factors including the number, age, and socio-economic characteristics of residents. These characteristics have not changed much in recent decades, with household size and composition remaining relatively constant. However, the increase in foreclosures due to the severe recession of the late 2000s did lead to a temporary reduction in per unit water use caused by the abandonment of many homes. At that time, there was also a temporary decrease in the number of single-family residential water accounts, although the number of accounts has been rebounding since 2018.

INDOOR WATER USE

The most common indoor water uses are from fixtures typically found in most homes, including toilets, showers, faucets, clothes washers, bathtubs, and dishwashers. Although the types of fixtures and appliances have not changed, there have been significant changes in how much water is used by most of these devices. Prior to 1980, most toilets used 5 gallons or more per flush, and there were many different models. Phoenix adopted a new plumbing code in 1980 that required toilets with efficiency levels of no more than 4 gallons per flush. In practice, this meant the installation of 3.5 gallons per flush toilets that were becoming the new *de facto* standard in North America in the 1980s. Federal regulations, triggered by the 1992 Energy Policy Act (EPAct), mandated even stricter efficiency standards for toilets starting in 1994 that became incorporated into plumbing code standards nationwide. While the City of Phoenix, the State of Arizona, and the federal government have not yet adopted a toilet efficiency standard that exceeds the 1.6 gallons per flush standard imposed in the 1990s, many states, including California, Colorado, and Texas, have implemented the EPA Water Sense specification of 1.28 gallon per flush, and this has led most retailers in Arizona to stock these types of devices and most home builders in Arizona to install them. As a result of extensive renovations and upgrades of homes in older neighborhoods, approximately a fifth of toilets in Phoenix homes built prior to 1975 have toilets that use 1.28 gallons or less per flush.

Clothes washers and dishwashers have followed the same trend. Prior to 1990, many clothes washers used more than 50 gallons per wash while later a *de facto* standard of approximately 40 gallons per wash in top loaders was adopted. Federal standards were initially enacted in the 1990s as a result of the EPAct (which is periodically updated), but the standards tended to lag actual efficiency levels in units readily available in the market. Before 2000, most clothes washers were top loading. The increased use of more efficient front-loading machines and advances in water-saving technologies in all clothes washers over the past couple of decades has dramatically reduced average water usage in clothes washers to less than half what it was in the 1990s. Today, some front-loading machines use as little as 12 gallons or less per load, and some top loading machines without agitators use 18 gallons or less per load. Stricter federal regulatory standards will undoubtedly reduce the number of very inefficient washers available in stores, but most units sold in stores or installed by builders will greatly exceed federal standards. The situation is almost identical with dishwashers – new units only use a fraction of the water used by 1990s units, and efficiency levels in most devices sold on the market exceed minimum federal regulatory standards. Consumers often seek out products with high ratings by the EPA's Energy Star and Water Sense programs, which exceed efficiency standards required by law.[20]

Studies of water use across the nation and in Phoenix show that one of the main reasons for the reduction in indoor water use since 1990 is more water-efficient toilets and clothes washers.[21] Water use associated with showers, faucets, baths, and leaks or miscellaneous uses does not appear to have changed much during that time. While the EPAct set a maximum shower head flow rate of 2.5 gallons per minute, most shower heads produce around 2.0 gallons per minute for an average 8-minute-long shower. Significant reduction in water use from showers would require 1.75 or 1.5 gallon per minute shower head standards instead of the current 2.5 maximum. The amount of water attributable to dishwashers and baths has declined, but the quantities are so small there is minimal impact on total indoor use. Figure 29 below shows how water use for different appliances has changed over time in Phoenix homes built from 1975 to 1984. Only toilets and clothes washers show a substantial reduction in water use over time as less efficient models are replaced.

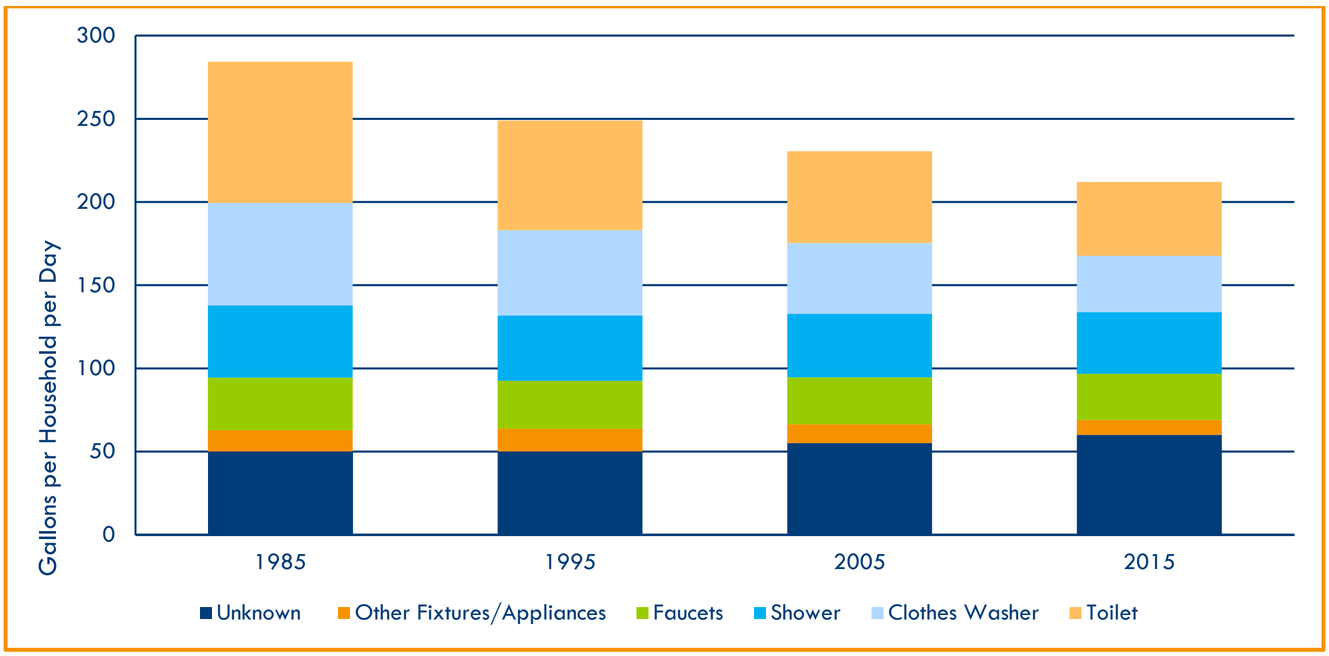


FIGURE 29. INDOOR WATER USE OVER TIME FOR HOMES BUILT FROM 1975 TO 1984

[20] Jenkins, L. (2021, April 8). *Most of the Public Says They Consider Their Individual Environmental Impact on a Daily Basis.* Morning Consult. https://morningconsult.com/2021/02/08/most-of-the-public-says-they-consider-their-individual-impact-on-a-daily-basis/

[21] Water Research Foundation. (2016). *Residential End Uses of Water (Version 2 – Executive Report)*. (2016, April). https://www.circleofblue.org/wp-content/uploads/2016/04/WRF_REU2016.pdf

When aging fixtures need to be replaced, or as homeowners choose to remodel kitchens and bathrooms, they are replaced with newer, more efficient fixtures. Moreover, there is not always a straightforward relationship between housing age, indoor water use, and fixture replacement rates in Phoenix and across the country. Replacement rates are often influenced by many socio-economic and cultural factors. For example, many of the oldest homes in Phoenix, which were constructed prior to 1960s, are in historic districts or other highly desirable areas. These neighborhoods tend to have relatively affluent residents and high housing prices, and as a result are frequently renovated or updated.

OUTDOOR WATER USE

Today, desert landscaping is the prevalent choice in Phoenix. It is well-accepted and well-integrated into the urban fabric of Phoenix, reflecting a mindful acknowledgement by residents and businesses of the City's Sonoran Desert setting and climate. Many existing homeowners and businesses have converted their landscaping from turf to desert landscaping over the years, and most new development has desert landscaping as an aesthetic preference.

FIGURE 30. EXAMPLES OF THE RANGE OF LANDSCAPING IN PHOENIX

Outdoor water use is largely associated with landscape irrigation, and to a lesser extent, swimming pools. Both residential and commercial landscaping in Phoenix is highly variable, ranging from homes with grass lawns accompanied by trees and shrubs characteristic of wetter, non-desert environments, to yards composed entirely of decomposed granite with cacti, succulents and other plants that are either native or highly adapted to the climate. This broad range of landscape plants is often tied to housing age, the availability of low cost SRP direct irrigation supplies, and neighborhood characteristics.

While for much of the 20th century Phoenix was described as an "oasis in the desert," characterized by citrus orchards and lush lawns, by the 1970s, concerns about excessive groundwater mining shifted public opinion (and water regulation) toward adoption of a desert lifestyle. Beginning in the 1980s and 1990s, new tract home developers began to diversify away from offering only full grass front yard lawns and instead offered more water-efficient landscaping as options. Over time, mixed and low water use landscaping gained more acceptance with homebuyers and today low water use landscaping, also known as xeriscape, is frequently the most common choice for new residences. This preference has also influenced back yard landscaping, with defined grass areas for children, pets, and outdoor activity, and the remaining landscaping being low water use, desert-adapted plants, or gravel.

Landscaping at older, existing homes also has been gradually shifting away from predominantly grass lawns and high-water use plants and trees, and towards low water use landscaping (Figure 31). This change is driven partly by a cultural shift away from grass lawns, as well as the perceived convenience and low maintenance costs of desert-adapted landscaping. Currently 10 to 15 percent of homes' landscapes are turf intensive, and across the City mostly or partially desert landscapes are the norm rather than the exception. However, the range of water use in these landscapes is significant due to the variability in the landscape and irrigation system designs.

FIGURE 31. AN OLDER HOME YARD CONVERTED TO LOW WATER USE, DESERT-ADAPTED LANDSCAPING

Landscaping choice can impact localized temperatures. In the Phoenix area, increasing nighttime temperatures have largely coincided with the rapid expansion of the urban area that started in the 1960s, creating the "urban heat island' effect. Buildings, sidewalks, parking lots, and hardscape are less effective at releasing heat at night absorbed during daylight hours compared to landscaped areas. The shift toward partial or complete desert landscaping that has occurred in the last two decades can mitigate this effect through adequate coverage and proper placement of trees that maximize shade and help reduce the absorption of heat. This is particularly important in denser, more urban neighborhoods with high levels of hardscape and building surface area.

Another important outdoor water use at single-family homes has long been swimming pools. From the early 1970s to the late 1990s, over 30 percent of single-family homes constructed during that period included swimming pools. For homes constructed after the late 1990s, the percentage is much lower, and by 2014, only 15 percent of newly-constructed homes had swimming pools (Figure 32). The decline in swimming pool construction is difficult to explain, but contributing factors appear to include an increase in the prevalence of community (HOA) pools, smaller lots, higher maintenance costs (both financial and labor), and changing demographics (fewer couples-with-children households). The decrease in popularity of swimming pools has led to a decline in per-unit water demand in newer homes, and this has had impact on overall water demand. However, many homes with pools can still have relatively low water use – a house with desert landscaping, a good irrigation system, and relatively recent appliances and fixtures and a pool will use significantly less water than a house with turf landscaping and older fixtures and appliances.

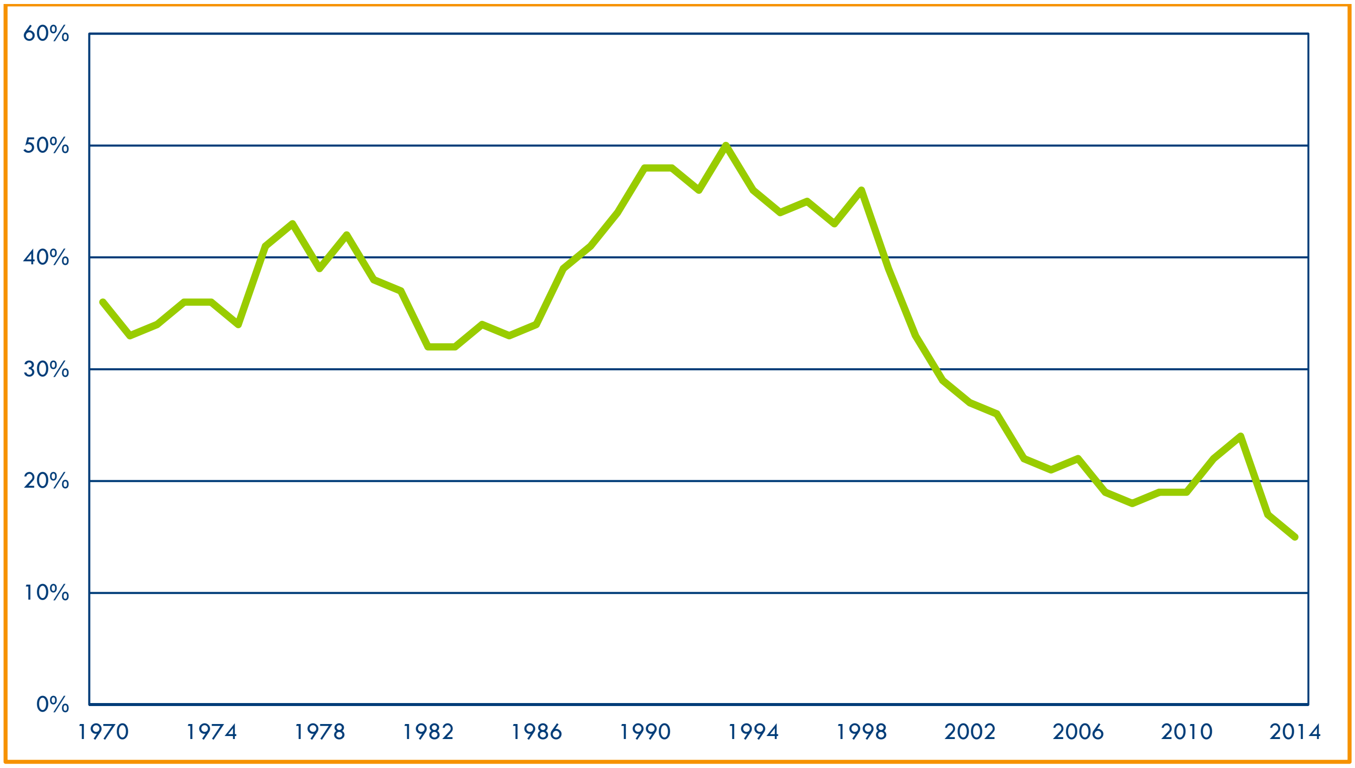


FIGURE 32. PERCENTAGE OF SINGLE-FAMILY HOMES WITH SWIMMING POOLS BY YEAR OF CONSTRUCTION

MULTIFAMILY WATER USE

In a city as large as Phoenix, multifamily developments are diverse and include apartment complexes, condominiums, townhouses, and other types of attached housing of various sizes and ages. The socio-economic makeup and household size of multifamily developments can also vary considerably.

Indoor water fixtures in multifamily developments are quite similar to single family homes. Differences largely rest with the fact that some older developments tend to have communal laundry facilities rather than clothes washers and dryers within individual living units. Also, meters or sub-meters for individual units are relatively uncommon, particularly for rental apartments. The use of common meters with no sub-metering of individual units can lead to higher water use through the fragmentation of responsibility – condominium or rental apartment residents that do not pay directly for the water used in their homes will often show less concern about economizing than those who have sub-meters or meters and must pay directly for water used.

Outdoor water uses at multifamily developments typically include landscaping, community swimming pools, and other common accessory uses for the development (spas, hose bibs, etc.). Like single-family homes, older developments tend to have more grass and higher water-use plants and trees. Conversely, new multifamily developments have relatively little lawn area and utilize mostly low water use landscaping.

Frequently, a key difference between multifamily development and single-family home water use is how water is managed. Multifamily developments usually have a property manager or management company that hires a landscaping management company to maintain the landscaping and irrigation system. For owner-occupied developments, a homeowner's association will choose a property management company and will usually weigh in on landscape related decisions. However, the division of responsibilities in multi-family developments can often lead to higher irrigation use, because the firm responsible for the landscape and irrigation system maintenance will face adverse reactions for dying or suboptimal vegetation caused by deficit irrigation but will generally not have an incentive to reduce water bills.

Older developments, many of which have considerable amounts of turf and high-water-use plants, often face challenges related to leaking pipes, aging valves, malfunctioning controllers, and frequent line breaks. For owner occupied developments, increasing maintenance, repair, and water costs associated with a variety of aging facilities (private streets, community centers, lighting, and drainage) can often overwhelm the financial resources of a homeowner's association and make costly repairs and upgrades to irrigation systems difficult to justify.

COMMERCIAL, INDUSTRIAL AND INSTITUTIONAL (CII) WATER USE

In Phoenix's water service area, CII uses account for only about 22 percent of all water use (exclusive of landscape use). Figure 33 shows the various CII sectors as categorized for billing purposes in Phoenix. Within the CII sector, water use is very fragmented and heterogeneous, and there are distinct usage patterns for the sectors. Hospitals, for example, are often equipped with vacuum systems, X-ray equipment, and sterilization equipment. Large, high technology industrial users often need to dissipate significant amounts of heat generated by equipment. Even within a water use sector, there can be a high degree of variability in water use patterns. All hotels and motels will have rooms with toilets, showerheads, and faucets, but they also may – but not necessarily - have restaurants, pools, ice machines, and other water uses. This diversity has several key implications. One is that the City's CII water demand is not dependent on a small group of large commercial or industrial users and is therefore more stable and consistent than might otherwise be the case. Another is that attempting to understand changes in water use is challenging because of the diverse and complicated nature of the customer base.

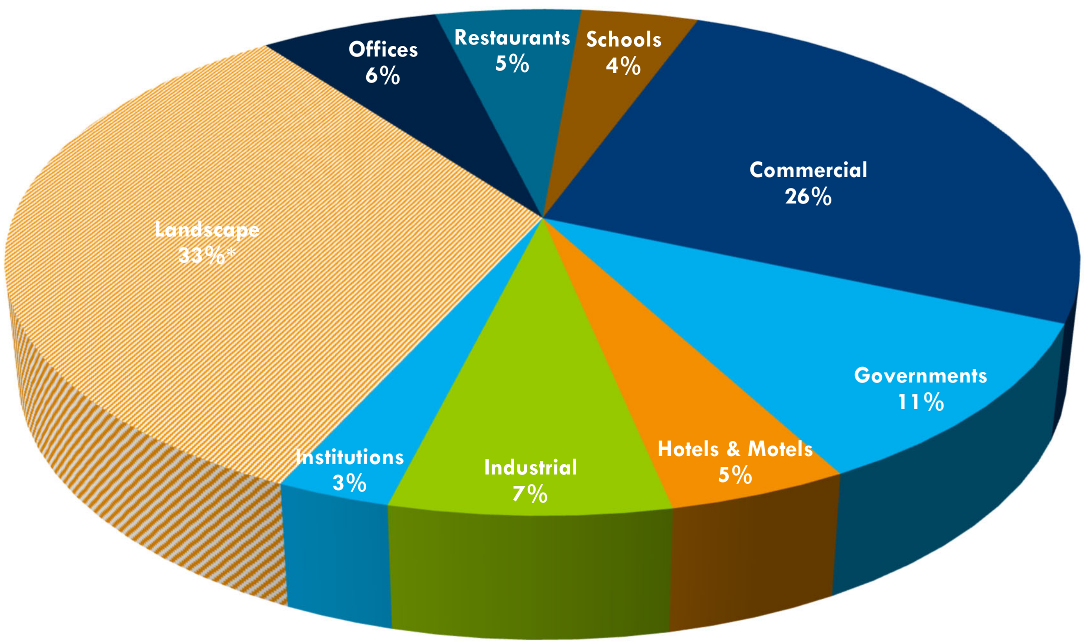


FIGURE 33. CII WATER USE SECTORS

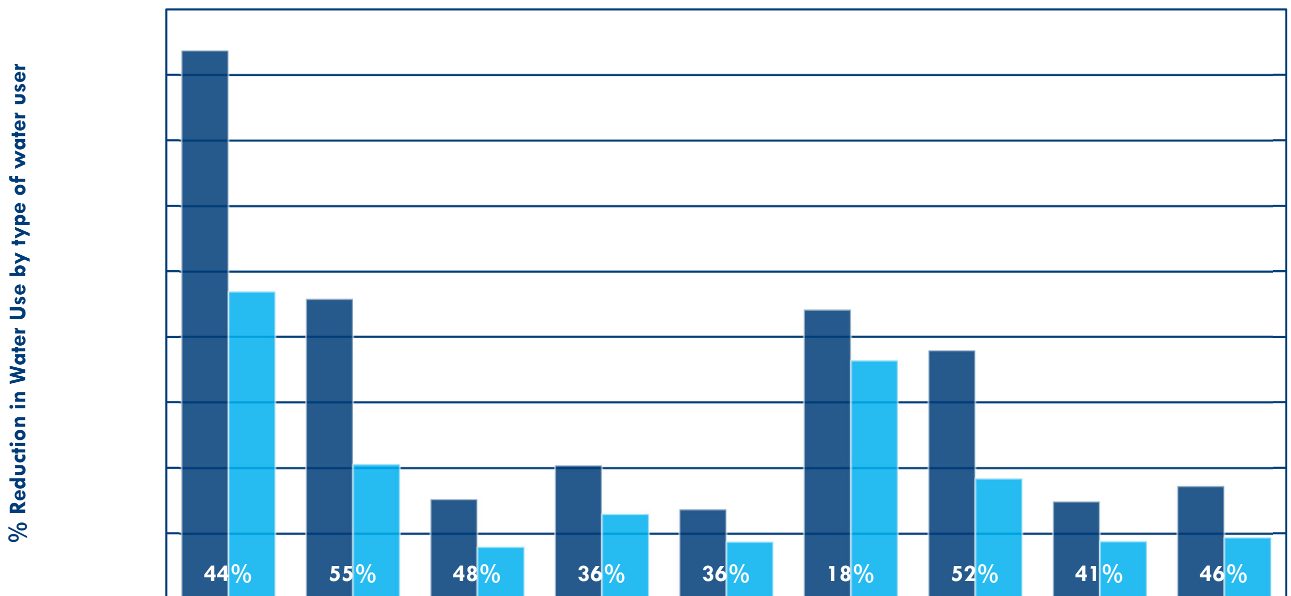
Because of their heterogeneous nature, the changes that occur in the CII sectors can vary greatly from each other. As a result, CII water uses are difficult to compare because there are few metrics that can be used year after year or decade after decade to analyze and compare water demand. Many studies conducted in the past have attempted to apply a single metric to multiple facility types, such as gallons per square foot per day. However, research by the City suggests that this approach misrepresents the changes in water use over time, which is essentially what needs to be understood. These changes include technological advances, size of a given facility, and increases in process efficiency.

Although Phoenix's population has increased by approximately 118,000 persons and its employment has increased by approximately 48,000 from 2002 to 2012, total water deliveries to CII customers decreased by nearly 2,000 AF over the same period.[22] The City of Phoenix initiated research of the CII sectors to identify the drivers of change in water use by CII customers in order to forecast and manage future water demand. By understanding these

[22] Population estimates of Phoenix's water service are derived from Maricopa Association of Governments annual population estimates. Employment data is from the 2002 and 2012 U.S. Economic Census.

factors, it is possible to define which facility types would benefit from specific water efficiency and conservation measures to reduce consumption as appropriate to the City's demand management policies relative to water supply availability.

A historic trend of declining water use is evident throughout the CII sectors from 1986 to 2016, which is shown in Figure 34. This figure shows the percentage reductions in water use for metered accounts that remained active from 1986 to 2016. Across the board, reductions have been substantial, ranging from a decline of 23 percent for landscape meters to 59 percent for government facilities, with an overall decline of 45 percent.



	Commercial	Government	Hotels & Motels	Industrial	Institutions	Landscape	Offices	Restaurants	Schools
1986 AF	16745	9157	3039	4074	2732	8831	7572	2970	3438
2016 AF	9384	4107	1586	2588	1743	7268	3669	1759	1874
% Reduction	44%	55%	48%	36%	36%	18%	52%	41%	46%

FIGURE 34. REDUCTIONS IN CII WATER USE BY SECTOR, 1986 TO 2016

Although several types of water use that are found in the residential sector are also found in CII sectors, the types of devices and equipment used by CII customers are also often distinctive and sometimes unique to the category or even firm/organization. Changes in technologies have resulted in significant reductions in water use. Table 6 below highlights of some of these changes and the resulting decreases in water use.

OLDER DEVICE, SYSTEM OR PRACTICE	REPLACEMENT DEVICE, SYSTEM OR PRACTICE	REDUCTION IN WATER USE
5 Gallons Per Flush Toilet	1.6 Gallons Per Flush Toilet	74%
3.5 Gallons Per Flush Toilet	1.6 Gallons Per Flush Toilet	63%
3.5 Gallons Per Flush Toilet	1.2/.8 Gallons Per Flush (Dual) Toilet	71%
1.5 Gallons Per Flush Urinal	0.125 Gallons Per Flush Urinal	92%
Commercial Washer Extractor (circa 2000)	Continuous Batch Washer (circa 2015)	70%
Commercial Food Waste Disposer (circa 2000)	Commercial Pulper (circa 2015)	71%
Pre-Rinse Spray Valve (pre-2005)	Pre-Rinse Spray Valve (circa 2015)	57%
Water Cooled Ice Maker	Air Cooled Ice Maker	85%
Medical/Dental Vacuum System (water-cooled)	Medical/Dental Vacuum System (air-cooled)	100%
X Ray Equipment (circa 1990)	Digital Imagery (circa 2015)	100%
Sterilization Equipment (circa 1990)	Sterilization Equipment (circa 2015)	80%
Cooling Tower, Older Lighting/Equipment (circa 2000)	Cooling Tower, New Lighting/Equipment (circa 2000)	13%
Cooling Tower, 2 Cycles of Concentration	Cooling Tower, 3 Cycles of Concentration	25%
Cooling Tower	Geothermal Cooling System	100%
Turf Landscaping (Aesthetic)	Desert Landscaping (Drip Irrigation)	50%
Turf Playing Field	Artificial Turf Playing Field	90%

TABLE 6. RAMIFICATIONS OF CHANGES IN DEVICES, SYSTEMS AND PRACTICES ON CII WATER USES

An example of finding the correct metric for comparison can be shown by examining hospitals and water use in Phoenix. In looking at total water use by property, it appears that water use has increased over time. However, even though water use increased, total building square area increased at an even faster rate. This is reflected in Figure 35, which shows that water use has decreased over time on gallons per day per square foot basis.

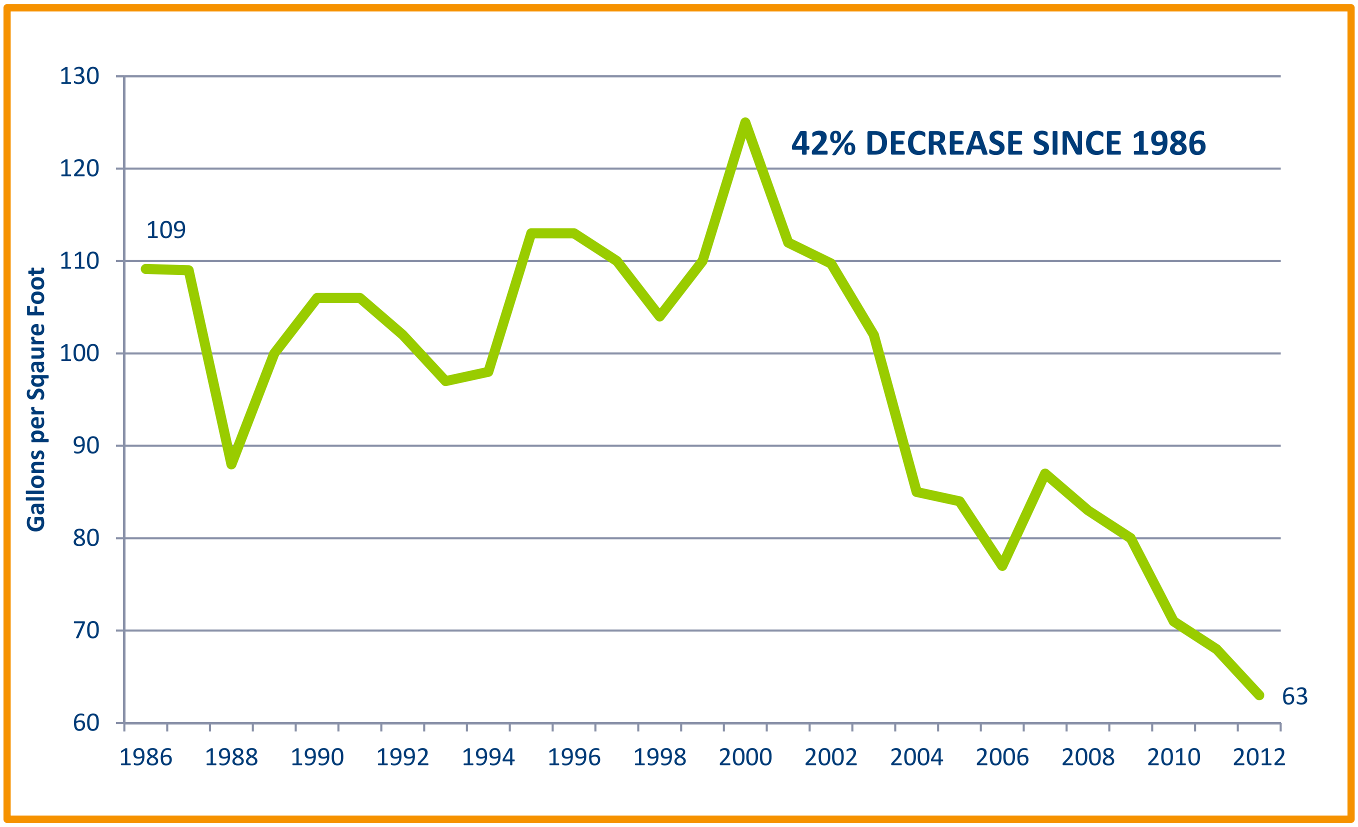


FIGURE 35. WATER USE AT ALL PHOENIX HOSPITALS[23]

While characterizing current water demand by its end uses is important to establish a baseline, identifying the various causes for changes in water using fixtures and devices is vital. These changes are often not directly related to water conservation, so it is important to understand all reasons for the changes. Devices that comply with the energy efficiency standards first established due to of the 1992 Energy Act also conserve water. Newer air-cooled ice machines use less energy, require less maintenance, and consume no cooling water, which can reduce water use per pound of ice by more than 80 percent. In some instances, evaporative cooling systems are replaced with heating, ventilation, and air-conditioning or HVAC systems that are very energy efficient and require little maintenance.

Many CII customers will replace or upgrade devices, equipment, and processes sporadically. For example, a hotel may see little or no change for twenty years, and then be completely renovated with new fixtures and appliances installed all at once. Similarly, cooling towers (commercial evaporative cooling systems) in large commercial buildings sometimes account for half of the water used in that facility but can dramatically reduce energy and water use with updated new equipment or processes. The relative efficiencies of these systems are directly affected by how well each system is managed and maintained.

[23] Water use intensity in gallons per square foot of building area for 13 hospitals from 1986 to 2012 of 13 hospitals that were audited by WSD and consultants

The City's future research will include further definition of the different categories of CII customers, including the quantification of water used by cooling towers, as well as outdoor water use reflected in both meters that are 'landscape' water meters and outdoor water use for non-landscape purposes. For many CII sectors, the two largest uses for water are for cooling towers or landscape irrigation. As warmer and drier conditions are likely to become the norm, the ability to assist CII customers in using water more efficiently will be essential to maximizing the use of available water resources.

Although the CII water use sectors have been variable and dynamic over time, the proportion of Phoenix's total water use from the CII sector has remained very consistent through the years. With further research needed to understand what may happen to CII water uses in the future, and with the inherent difficulties of predicting how the national and local economies will evolve over the next fifty years, this historical consistency is a key assumption for the water demand projections elaborated upon in Chapter 4.

Geographic Differences in Water Demand and User Characteristics

ON-PROJECT VERSUS OFF-PROJECT DEMAND

As more fully described in Chapter 2, areas entitled to water allocations from the Salt River Project (SRP) are known as on-project areas, while the remainder of the City is often referred to as off-project. Because of the different legal and physical availability of supplies between on-project and off-project areas, water demand for the two areas is evaluated separately.

The City's original townsite is located on-project, surrounded by SRP member lands. Much of the City's residential and commercial growth radiated outward from the townsite onto the surrounding farmland that was irrigated by the Salt River Project. Most of the pre-World War II and early post-World War II expansion period, as a result, was largely on-project. Today, water use within on-project areas is roughly half of the City's total demand.

Starting in the 1960s, development – predominately single-family residences and retail -- grew even further outward, and most of the large tracts of land available for development were off-project. Today, most large-scale new development is occurring in far north Phoenix, which is north of the CAP canal, or in southwest Phoenix. While on-project and off-project demands are distinct from one another, there is some overlap where housing and non-residential development are similar in age, character, and water use. However, the off-project portion of the City is generally newer, constructed during an era when conservation and regulatory requirements, and technological specifications and customers' preferences improved water use efficiency compared to what was built on-project.

Another growth pattern that has emerged on-project since the Great Recession in 2008 is infill and higher density redevelopment in the downtown areas of the City. Much of this downtown development and redevelopment came with the expansion of Arizona State University and the University of Arizona downtown campuses. These areas are mostly on-project and while the number of mostly multi-family housing units continues to increase dramatically in the downtown and Central Avenue corridor of the City, it has not resulted in significant changes in water demand. This is likely because of the lack of acreage associated with landscaping for these buildings and installation of newer, more efficient plumbing fixtures. The fact that many of these higher density population areas are on-project has also minimized the overall impact on the City's water portfolio, as much of the on-project allocation from SRP was unused by older low-rise development or vacant barren hardscapes that previously occupied these properties.

A legacy of the early development pattern within on-project lands is "flood irrigation." SRP typically delivers between 40,000 and 50,000 AF per year of non-potable canal water for landscape irrigation purposes within Phoenix and approximately 14,000 acres are eligible for such deliveries. Use of flood irrigation has been trending slowly downward. This is likely due to such factors as redevelopment projects opting for drip irrigation and sprinkler systems and changing customer preferences for landscaping and irrigation system maintenance. While this trend may reduce the total water use on such lands, the conversion to potable supplies for landscape watering may increase City water demand for these areas.

LOCALIZED CHARACTERISTICS AND SOCIO-ECONOMIC EFFECTS

Water use patterns vary by geographic area even within the on-project and off-project areas. As discussed earlier, water use at older homes is trending downward and converging with that of newer homes as more of these homes have yards converted to desert-adapted or mixed landscaping, and high-efficiency devices are installed during renovations, upgrades, and replacements. In fact, many of the very oldest homes in Phoenix now use less water than newer homes because extensive renovation has become so common in large-lot homes built prior to 1970.

Another key element in the spatial distribution of demand is the accepted lifestyle or culture of households. While some higher income areas of the City's service area have high per-capita water use because a lush, green environment is considered desirable and customers are willing to pay for water for landscaping, other higher-income areas have embraced low water use landscaping. This is particularly true in the newer parts of the City. This concept is shown in Figure 36, which illustrates vegetation cover at residential parcels. Neighborhoods such as north central Phoenix and Arcadia, which have considerable flood irrigation, tend to have high vegetative cover (which correlates with larger amounts of grass and non-desert adapted plants and trees). By contrast, areas north of the CAP canal show lower vegetative cover. Results of aerial imagery analysis of residential landscapes indicates that desert landscaping is gradually being adopted in virtually all areas of the City, but at different rates, indicating that neighborhood culture plays a role in the use of water for irrigation. Many of the areas with the most water-intensive landscapes also paradoxically show relatively low potable water use because the land uses in those older-housing-stock areas rely heavily on SRP direct deliveries or other small irrigation districts for irrigation water.

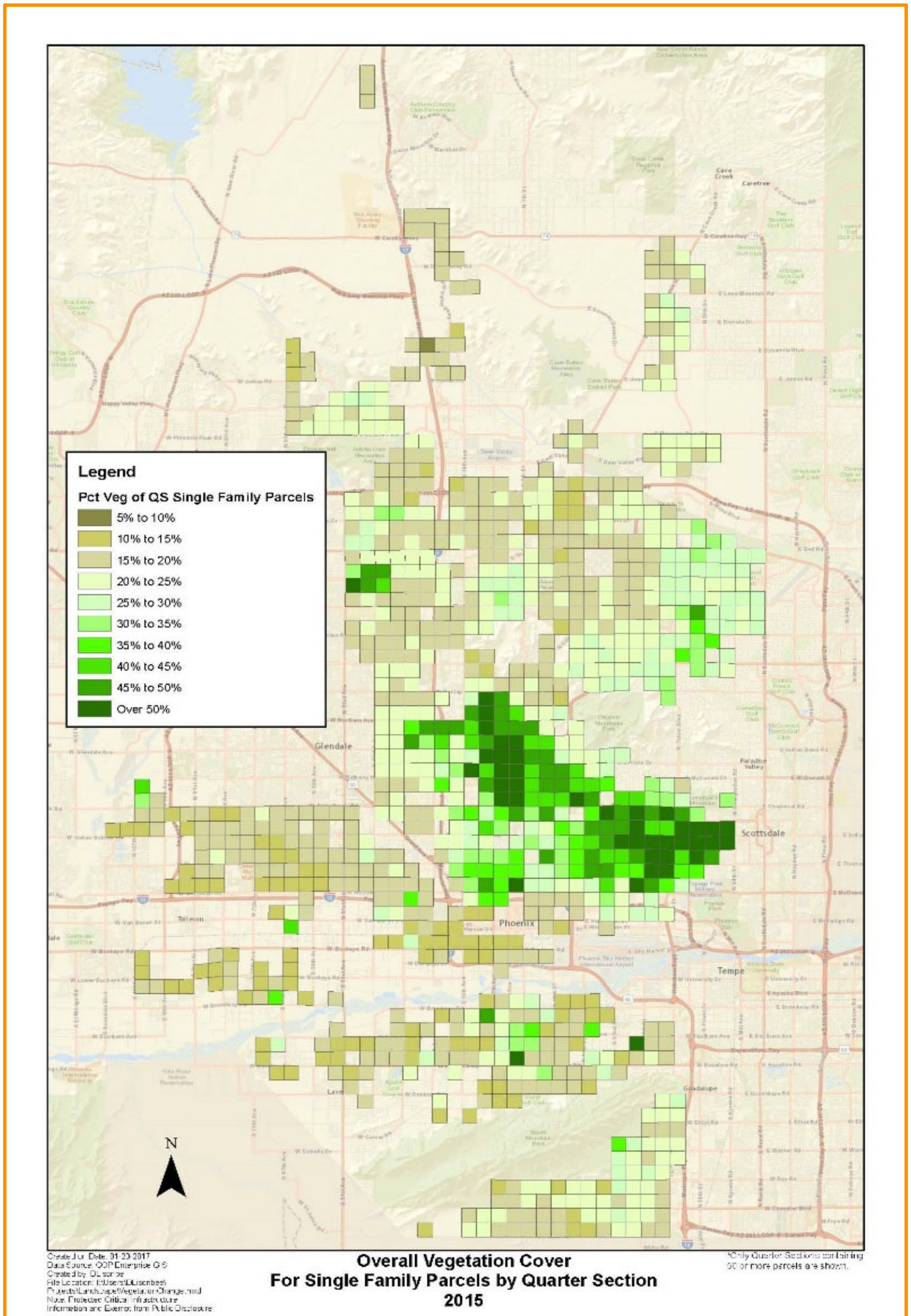


FIGURE 36. VEGETATION COVER OF SINGLE-FAMILY PARCELS

As described earlier in the chapter, the urban heat island effect can increase nighttime temperatures due to a lack of tree shade or vegetation. While landscape choices can vary considerably based on the age and neighborhood culture of the developed area, especially for affluent areas, lower income areas generally have less vegetative cover. This is particularly true in more urban subdivisions built from the 1950s to 1980s. As a result, less affluent areas of the City may be more exposed to higher nighttime temperatures than otherwise expected.

Seasonal System Demands

It is important for Phoenix when managing its water resources and establishing infrastructure needs and design standards to understand how water usage varies seasonally by its customers. Not surprisingly, water use in Phoenix, like many other cities in the Sonoran Desert, is considerably higher in the summer months. This is largely due to landscape watering needs, which dramatically increase with the higher temperatures, lower humidity and the resulting higher evapotranspiration of summer. However, water use during the summer has been trending steadily downward at a more rapid pace than indoor water use. This trend is shown in Figure 37, which compares water use in July and February from 1986 to 2018. July tends to be the highest water use month and is the best proxy for maximum summer landscape watering needs, while February is the lowest water use month, and reflects largely indoor (non-landscape) water use. While February water use has declined, the declines in July have been more dramatic, reducing the difference between summer and winter water use. The shift towards mixed or desert landscaping with inorganic mulch results in lower water use, particularly in the hotter summer months, because desert landscaping is more tolerant of summer conditions. In addition, volumetric water rates are highest during summer months, June through September. This rate structure encourages efficient water use during peak demand months. The variation in the summer rate may incentivize customers to reduce water usage by utilizing water efficient or drought tolerant vegetation in landscapes. Desert adapted plants and trees require less water than non-native tropical varieties and may require no additional water over precipitation once established. This preference for less water-intensive landscapes has become much more prevalent over the past couple of decades.

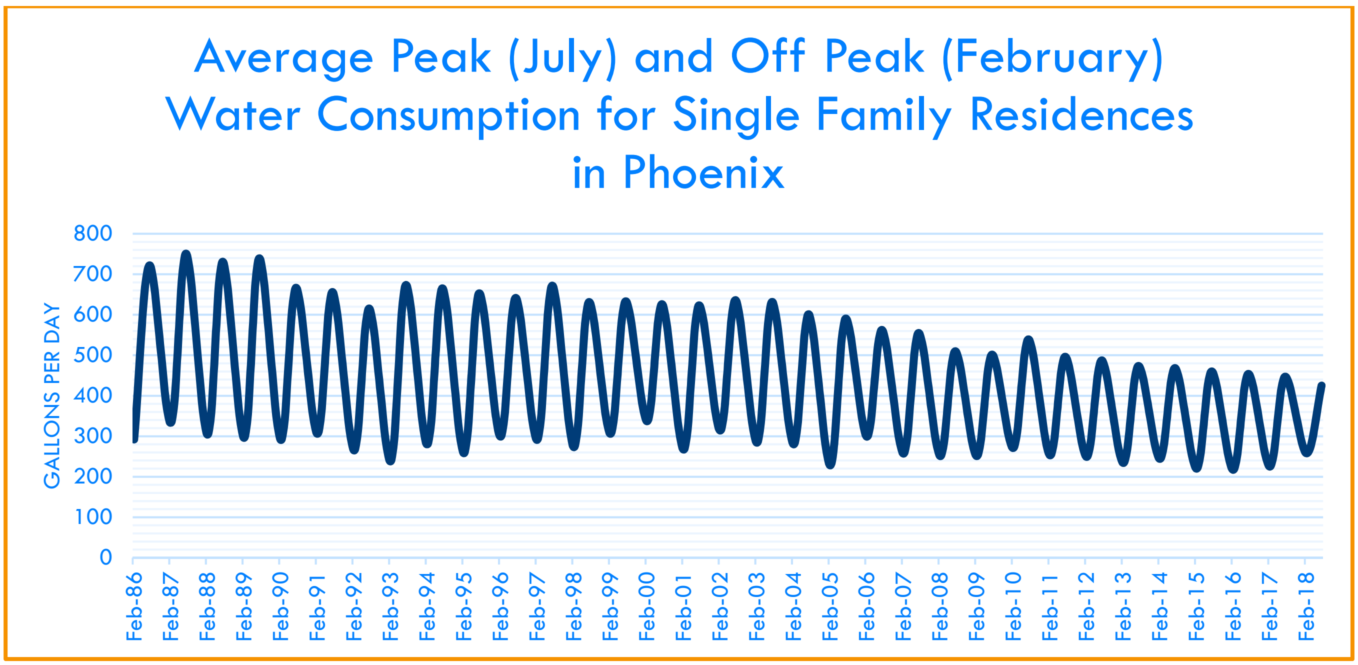


FIGURE 37. PEAK VS OFF PEAK DEMAND, 1986-2018

While the reductions in summer peak water use are most tangible for sizing of water infrastructure such as mains and plant capacity, there are potential ramifications for water resource planning as well. For example, reduced summer demand may offset the effect of reduced Normal Flow available for on-project lands during the summer months that may occur due to changes in the timing, amount, and duration of spring runoff from the Salt and Verde Rivers.

3.2 Key Drivers for Future Water Demand

Population and Employment Growth and Residential and CII Development

Phoenix's economy, growth areas, and housing needs and preferences have changed greatly since the "Great Recession". Phoenix has experienced significant economic variability in the past two decades, but the overall water demand has continued to decline. It is difficult to ascertain whether these new patterns will continue or revert to what had occurred in the past, but these future patterns will no longer correlate with overall water demand. Varying economic factors combined with declining water demands create uncertainty when projecting future water needs.

As previously noted, multifamily construction has grown as a proportion of overall residential construction units, reflecting both an increased interest in urban living by all age groups. Households have become diverse, with increasing proportions of homes occupied by single residents, single parents with children, and multi-generation families. Fertility rates of American women have fallen to levels not seen since the Great Depression, and many young adults are electing to live at home with their parents longer, changing the demand for various types of housing.[24] Previous employment patterns have also been altered in the past two decades: The total number of people employed in the high technology and defense-related manufacturing sectors has not increased since 2000, and the retail sector is facing major challenges from the growth of online shopping, which have only grown since the beginning of the COVID-19 pandemic in March 2020. In addition, the number of people working from home has exponentially increased as a result of COVID-19 restrictions. These trends related to the shift to e-commerce and remote work are expected to continue well-past the end of the pandemic.[25]

Phoenix is growing in terms of both population and employment, but in significantly different ways, than was experienced during the 1950 to 2000 period. Single family home construction during the 1970 to 2000 period was approximately 5,000 units a year, but the level was closer to half that until 2017 when it increased to about 3,800 units per year. Given the shortage of labor and materials, there is pent-up demand that will fuel the growth for the foreseeable future.

[24] Hamilton BE, Martin JA, Osterman MJK. Births: Provision data for 2019. Vital Statistics Rapid Release; no.8. Hyattsville, MD: National Center for Health Statistics. May 2020. Available from: https://www.cdc.gov/nchs/data/vsrr/vsrr-8-508.pdf;
[25] McKinsey Global Institute. (2021). *The Future of Work After COVID-19.* https://www.mckinsey.com/featured-insights/future-of-work-after-covid-19#

Growth in single family water accounts was roughly one percent in 2018. With major automation and other technological changes still ongoing, significant employment growth is unlikely to take place in the manufacturing, warehouse, or retail sectors, even if more goods are produced and distributed locally.[26]

Water Efficiency – Single Family, Multifamily and CII Trends

In Phoenix, as in the United States, total water usage peaked in the 1990s and has since declined slightly even as population and employment has increased. The reasons for this per-capita water use decline include: 1) The movement away from water intensive landscaping to desert landscaping; 2) greatly improved efficiencies for toilets (Figure 38), clothes washers, and dishwashers driven by federal specification programs and manufacturer's design improvements; and 3) improved efficiencies for the CII sector due to technological changes and a drive to reduce energy and water costs.

Research by the City of Phoenix and many national and local organizations now indicates that per-resident and per-employee water use will continue to fall as customers gradually upgrade to more efficient devices and landscapes. The exact rate of change cannot be predicted but establishing a probable range of change can be accomplished by estimating the current types of landscaping, fixtures, appliances, and other devices found in homes and businesses, and then by projecting what will happen when users adopt more water efficient systems at a likely range of rates.

[26] World Economic Forum. (2020). *The Future of Jobs.* https://www.weforum.org/reports/the-future-of-jobs-report-2020

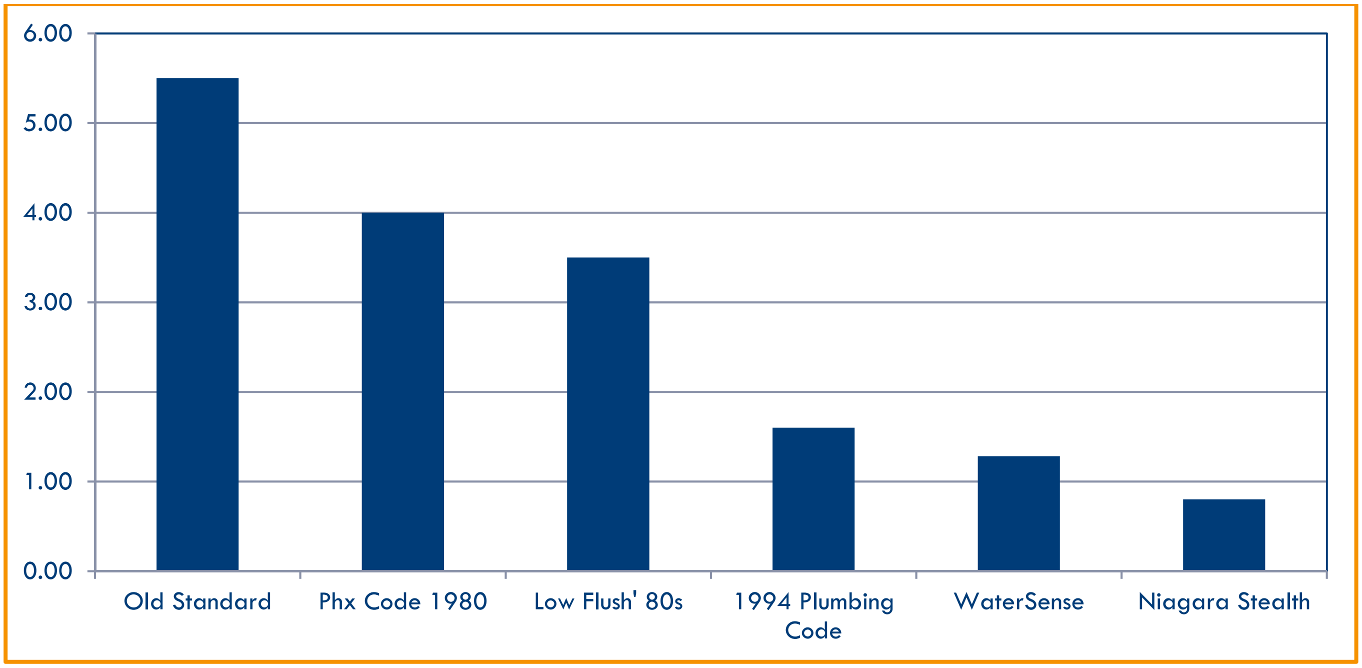


FIGURE 38. TOILET EFFICIENCY GAINS (GALLONS PER FLUSH): 1970 TO PRESENT

CHAPTER 4 – SUPPLY AND DEMAND PROJECTIONS

Chapters 2 and 3 clarify why longstanding paradigms regarding drought duration and water demand must be challenged. Chapter 2 outlines recent research that explains the potential depth and duration of water supply shortages caused by climate change on the Colorado River and Salt and Verde Rivers watersheds. Chapter 3 explores how technology and customer preferences have caused water demand in Phoenix to largely decouple from its traditional relationship with population and economic growth since the mid-1990s.

The implication of these significant changes is that water resource planning decisions cannot be based on a single scenario. Rather, with a greater potential for uncertainties regarding future outcomes, a more practical approach starts with defining the "unknowns" that could affect future planning decisions. Some of these unknowns can be explored by minimizing uncertainties through scenarios that explore anticipated outcomes.

To accomplish this, variations in individual factors such as surface water availability, groundwater availability, development density, water efficiency, and growth rate are combined to form scenarios. These scenarios provide context for the uncertainties and provide a more realistic picture of how a solution could address multiple outcomes. The iterative planning process, supported by frequent monitoring of actual conditions and the establishment of trigger events or dates, allows the City to deploy necessary supplies and programs while avoiding premature resource commitments and stranded assets.

4.1 Process for Developing Scenarios and Shortage Estimates

By varying SRP availability, CAP availability, growth level, and water use efficiency, we can explore different scenarios that impact water resources. General ranges within these scenarios are illustrated in Figure 39 and described in the following sections.

Salt and Verde River Supplies	Full availability	↔	Reduced availability
Colorado River Supplies	Full availability	↔	Reduced availability
Growth and Development	Low rate	↔	High rate
Per-Unit Water Use	High efficiency gains	↔	Minimal efficiency Gains
	↓		↓
Probability of Deficit	Low	↔	High

FIGURE 39. CONCEPTUAL PROJECTION RANGES

4.2 Supply Scenarios

Two water supply scenarios represent the full range of supply available to Phoenix anticipated through the year 2070:

- Normal supply conditions with inflows adjusted for climate change (high water resource availability); and
- Historic drought conditions and inflows adjusted for climate change (low water resource availability).

Both water supply scenarios rely on measured or modeled natural flow data records (since 1900 for the Salt and Verde Rivers and since 1906 for the Colorado River) used in conjunction with historic modeled flow based on tree ring records evaluated by researchers at the University of Arizona (back to year 1199 for the Salt and Verde Rivers and 1279 for the Colorado River). The use of tree ring records and modeled flow data provides a much more extensive inflow history in which to capture the potential frequency, length and probability of long term dry and wet cycles on both river systems.

The supply projection scenarios do not simply replicate past conditions, however. Potential climate change effects on temperatures, precipitation, evaporation, snowmelt and runoff are also considered. As discussed in Chapter 2, climate change is expected to increase temperatures and evaporation in the southwestern United States, potentially accelerating snowmelt and causing stream flows to occur earlier in the year. Many climate change models also predict more variable inflows; while the long-term average inflows are projected to decline, there may also be occasionally very wet conditions.

The two supply scenarios assume similar conditions will occur on both the Salt and Verde Rivers and Colorado River simultaneously, that a long cycle of relatively “normal” inflows is expected on both river systems for one of the scenarios, while a long cycle of dry conditions will occur simultaneously for both river systems for the other scenario. As described in Chapter 2, the Salt and Verde Rivers and Colorado River can enter simultaneous long-term dry cycles, but this has not always been the case. In order to fully “test” the availability of water supplies to Phoenix now and in the future relative to water demand, the most extreme, but plausible, situation of simultaneous long-term drought was used. Colorado River inflows adjusted for climate change have been provided by the BOR and ADWR as a courtesy to the City. The CAP’s inflow projections have been used to model Lake Mead water levels, which, as described in Chapter 2, can trigger reduced amounts of Colorado River water available to Arizona – and potentially Phoenix - depending upon how low Lake Mead elevations are projected to go.

SRP has recently been modeling the potential effects of climate change on the Salt and Verde Rivers in order to forecast supply allocations for its customers. Recent research conducted by SRP suggests that an annual delivery of up to 900,000 AF to its customers can be sustained for the indefinite future, including conditions of prolonged drought and climate change projections. SRP has established a 2035 corporate goal of providing at least 2.5 AF/acre of water for its customers, with mixture of surface and groundwater supplies that have no more than 0.5 AF/acre of the total from groundwater sources. More details can be seen in the *Salt and Verde River Reservoir System SECURE Reservoir Operations Pilot Study*.[27]

The Colorado River and Salt and Verde River projections use historic data as a basis for future projections and are meant to be approximate and without great precision. The probability of annual future runoff on either river system exactly matching the historic record (albeit adjusted for climate change) is highly unlikely. In addition, the high degree of annual variability of runoff found on either river system (which may be exacerbated by climate change) creates a great deal of uncertainty as to when, if, and how long shortage conditions will endure. This does not mean the projections are not a useful tool. However, they are best used to assess the frequency and the aggregate quantity of shortage over the entire projection period rather than pinpointing the exact conditions of any particular year.

Considering that significant impacts to supplies could occur during the next decade, the City will continue to quantify the potential impacts of supply shortages. Based on any potential shortages, Phoenix will explore a wide range of measures that can be used to reduce or mitigate the effects of shortage.

4.2.1 Salt and Verde River Supply

Phoenix receives an annual allocation of water from SRP that has been at least 3.0 AF/acre over the past two decades, except in 2003 and 2004 when the allocation was reduced to 2.0 AF/acre. Even in those two years of reduced allocations, Phoenix was able to serve customers without supplementing SRP deliveries with water from other sources. If prolonged reduced flows on the Salt and Verde Rivers result in a reduction in the allocation Phoenix receives, it is unlikely to have any significant impact, because Phoenix current on-project demand is well below SRP's allocation and is unlikely to significantly increase in the future. The newly established SRP 2035 Sustainability Goals to ensure minimum deliveries reflects annual deliveries of up to 900,000 AF to SRP eligible lands. SRP performed extensive modeling efforts to analyze the effects of climate change to establish a sustainable baseline delivery goal. Using the 2.5 AF/acre metric, it is unlikely that Phoenix would ever be vulnerable to shortages from deficit flows on the Salt and Verde River systems. Phoenix currently uses about 1.74 AF/acre of water on SRP eligible lands. This total amount includes Normal Flow water, which is water available to Phoenix in addition to the total allocation. Over the past decade, up to 40% of the total water delivered to Phoenix by SRP has been Normal Flow water (41,000 AF average 2009 - 2020). In 2018, Phoenix received 145,000 AF of water of which 34,000 AF was Normal Flow.

The relationship between demand and supply is highly intertwined and interdependent. As remaining SRP shareholder lands within Phoenix urbanize, these lands will be "cut over" to

[27] US Bureau of Reclamation, Study Report, January 2020 (usbr.gov/watersmart/pilots/docs/reports/Final_Reservoir_Operations_Pilot_Report-Salt_and_Verde_Az.pdf).

Phoenix for treatment and delivery to its customers (see Chapter 2 for a discussion of cut over acres). The supply scenarios are adjusted to account for pace and quantity of shareholder lands cut over to Phoenix relevant to the underlying assumption for each demand scenario described below.

4.2.2 Colorado River Supply

As noted elsewhere, Phoenix currently has 186,557 AF of Colorado River water available annually through its subcontract, NIA contracts and long-term leases from tribal communities. In addition to those supplies, Phoenix has a leased 3,505 AF of Colorado River water from the White Mountain Apache Tribe which should be available to Phoenix beginning in 2025 as a result of a water rights settlement approved by Congress in 2010.[28] Phoenix is also expecting a transfer of 12,000 AF from Arizona State Land Department's Municipal and Industrial subcontract to Phoenix's subcontract by 2026, pursuant to an Intergovernmental Agreement between the parties.[29]

Figure 40 shows Lake Mead levels since 2000. As of April 2021, Lake Powell's 24 million AF capacity is 35 percent full. Lake Mead's 25.8 million AF capacity is 38 percent full with a water level elevation at 1,080 feet above mean sea level. As described in Chapter 2, storage between the two reservoirs is equalized by the BOR, based on criteria contained in the 2007 agreement for the Interim Guidelines for the Operation of Lake Powell and Lake Mead.

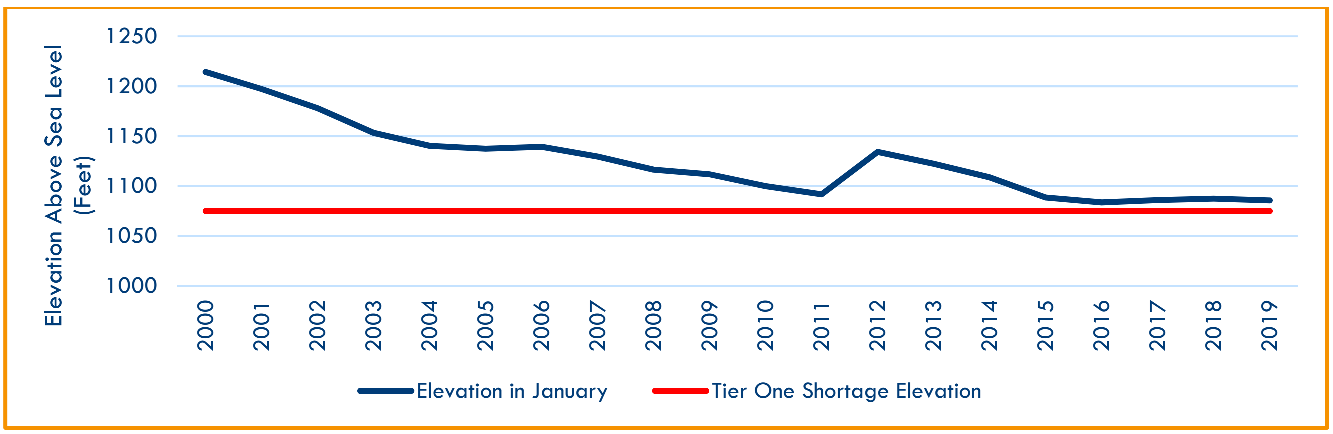


FIGURE 40. LAKE MEAD ELEVATION LEVELS SINCE 2007

The BOR's long term projections that are used as a basis for this plan's supply scenarios do not assume any policy or associated actions on the part of the Lower Basin States or the Secretary of the Interior to mitigate shortages on the Colorado River. This is significant, particularly regarding the scenario that projects historic drought conditions with climate change. Using this

[28] Timeframes for the final actions by Congress necessary for Phoenix to lease this supply have not been set. However, for the purpose of these projections, the supply is assumed to be available in 2025.

[29] Intergovernmental Agreement Between the Arizona State Land Department and the City of Phoenix to Facilitate the Development of State Trust Lands Within the City of Phoenix, Contract # 153015-0, October 6, 2020.

scenario, Lake Mead's water level can continually decline with no adjustments in demand or supply, despite the highly negative ramifications for the Lower Basin States. This is not consistent with the Interim Guidelines (See Section 2.3), effective through 2026, which already provide "shortage" reductions in deliveries in Central Arizona based on declines in Lake Mead elevations. The Interim Guidelines, and the subsequent 2019 Lower Basin Drought Contingency Plan (LBDCP) are examples of specific or collective policies that are agreed upon by the Lower Basin States or imposed by the Secretary of Interior and the BOR to mitigate potential shortages in Lake Mead. Based on the combination of the Interim Guidelines and LBDCP, in effect through 2026, Central Arizona's allocation could be reduced by as much as 720,000 AF if Lake Mead's water levels are projected by the BOR to fall below 1,025' below mean sea level. While there is no agreement to date that dictates the level of reductions to Central Arizona's Colorado River allocation after 2026, it is unlikely reductions would be less than those required by the Interim Guidelines or the 2019 LBDCP.

4.2.3 Groundwater and Recovery of Long-Term Storage Credit Assumptions

As described in Chapter 2, the City's wellfield currently can produce about 23,000 AF annually, if the wells pump approximately 65 percent of the time (pump duty). One assumption associated with all supply scenarios is that when surface water supplies are insufficient to meet demand, the City could increase well production up to permissible regulatory limits to compensate as much as feasible for any shortages.[30] Groundwater pumping is conducted in compliance with the City's Designation of Assured Water Supply and for recovery of long term storage credits banked to hedge against surface supply shortages.

4.2.4 Reclaimed Water Supplies Within the City's Service Area

The City will continue to maintain infrastructure to deliver reclaimed water to golf courses and other turf-related facilities in North Phoenix from the Cave Creek Water Reclamation Plant (CCWRP). In the absence of reclaimed water from the CCWRP, the reclaimed infrastructure has delivered a combination of raw CAP water and potable water. To date, deliveries have not exceeded 2,000 AF per year. For purposes of this analysis, this value was held constant through the 50-year projection period. CCWRP has an operational capacity of 8.0 MGD and can be expanded to a capacity of 32.0 MGD. Although the proposed rehabilitation and expansion of CCWRP by 2025 will likely result in additional opportunities for reclaimed water use, these supplies were not considered for purposes of this analysis.

The underlying water supply assumptions for the scenarios are shown in Table 7, which follows. While the assumptions include the development or expansion of direct potable reuse of reclaimed water, the amounts that would be generated are unknown and were not included as available supplies for this analysis.

[30] Well permits specify maximum pumping rates and volumes to comply with ADWR's well spacing rules.

TYPE	LEGAL AVAILABILITY	ASPECT	MEDIAN CONDITIONS ADJUSTED FOR CLIMATE CHANGE	DRIEST CONDITIONS ADJUSTED FOR CLIMATE CHANGE
COLORADO RIVER SUPPLIES	Entire Service Area	Inflows	50-year median historic flow adjusted for climate change (courtesy of CAP)	50-year driest historic flow adjusted for climate change (courtesy of CAP)
SALT AND VERDE RIVER SUPPLIES	Variable (see below)	Inflows	50-year median historic flow adjusted for climate change (25% gradual reduction in runoff)	50-year driest historic flow adjusted for climate change (25% gradual reduction in runoff)
	SRP Shareholder Lands	SRP Normal Flow	2001-2015 average with a corresponding adjustment with reduced inflows (see above)	2001-2015 average with a corresponding adjustment with reduced inflows (see above)
		SRP Stored and Developed Water	Adjusted to correspond with reduced inflows; annual allocation cut relatively less frequently	Adjusted to correspond with reduced inflows; annual allocation cut relatively more frequently and deeply
		Cut over acres	Dependent upon demand scenario evaluated	Dependent upon demand scenario evaluated
	Entire Service Area	Roosevelt Dam "New Conservation Space"	Inflows afford more frequent and larger replenishment of NCS supplies	Inflows cause less frequent and smaller replenishment of NCS supplies
		Verde River "Gatewater"	Inflows afford more frequent and larger replenishment of Gatewater supplies	Inflows cause less frequent and smaller replenishment of Gatewater supplies
		RID Exchange	Ends with urbanization of SRP lands	Ends with urbanization of SRP lands
GROUNDWATER / CREDIT RECOVERY	Entire Service Area	Pump Capacity	Maintain 2017 capacity	Additional Wells and Pumping Capacity
RECLAIMED	Entire Service Area	Within Service Area	Development of Direct Potable Reuse	Expansion of Direct Potable Reuse
		Outside Service Area	Development of Direct Potable Reuse	Expansion of Direct Potable Reuse

TABLE 7. GENERAL WATER SUPPLY PROJECTIONS SCENARIO ASSUMPTIONS

4.2.5 Reclaimed Water Supplies Outside the City's Service Area

Reclaimed water committed for uses outside of the service area is not specifically included in this analysis. Section 2.6.3 describes the long-term agreements and obligations for reclaimed water from the 23rd Avenue and 91st Avenue wastewater treatment plants for use outside of the service area. While some of the agreements expire prior to 2070 which might make available supplies that could be directly or indirectly used within the service area, these supplies are not assumed to be available to meet service area demand with this analysis. Phoenix does plan to reopen the Cave Creek Water Reclamation Plant to meet growing demand in North Phoenix, including a potential for direct potable reuse of effluent within the service area. This deficit mitigation strategy, as well as many others, is covered in Chapter 5, but is likewise, not included in this analysis.

4.2.6 Supply Projection Results

Figures 41 and Figure 42 show the supply projection results for on-project supplies compared to supplies that can be used throughout the City, respectively. Each chart shows the average annual supplies available throughout the projection period for each scenario. Bifurcating supplies in this way is necessary in order to reflect the availability and priority of supplies for on-project lands versus those supplies available for either on-project or off-project use. On-project areas of the City will first use SRP supplies, because it is appurtenant to the land and readily available to water treatment plants that serve this area of the City. While it is possible that non-SRP supplies will be needed to meet any on-project water demands if SRP supplies are not adequate, this has happened very infrequently in the past. For this reason, only SRP supplies are included in Figure 41, although it is within the realm of possibility that non-SRP supplies may be needed. Figure 42, by contrast, shows the supplies that can be used citywide for each scenario. If these supplies are not needed on-project, which as discussed above, seems very likely, they are used to meet off-project demand.

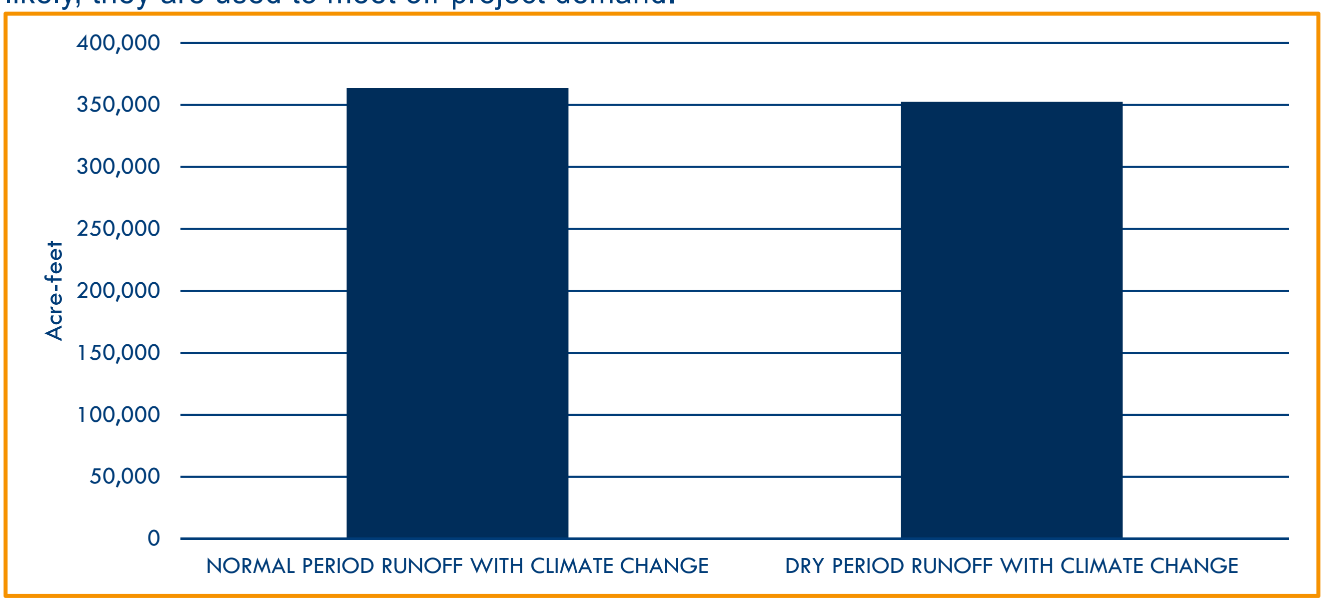


FIGURE 41. PROJECTED AVERAGE ANNUAL "ON-PROJECT" OR SRP SUPPLIES AVAILABLE BY SCENARIO

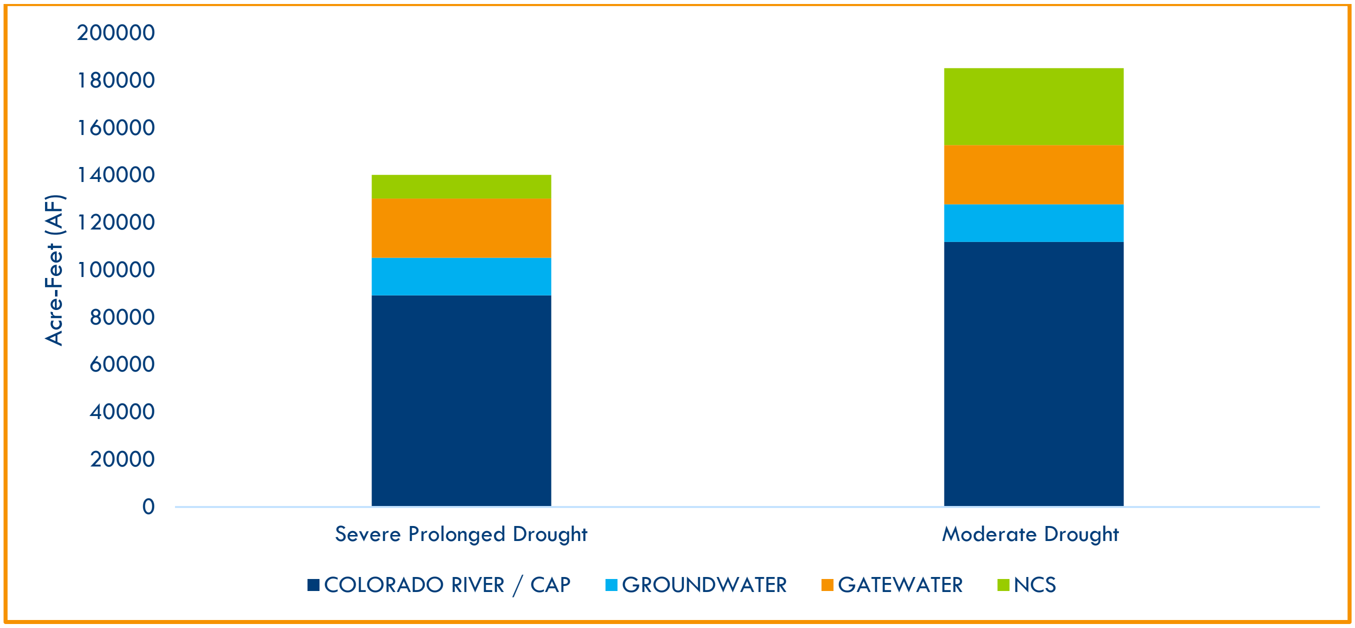


FIGURE 42. PROJECTED AVERAGE ANNUAL CITYWIDE SUPPLIES AVAILABLE BY SCENARIO

4.3 Demand Scenarios

4.3.1 Using Scenarios to Project Water Demand

Having different water demand scenarios is important for projecting the future. While the City has done considerable research regarding water demand and the identification of general trends, it is extremely difficult to gauge the degree to which these trends will accelerate or decelerate. Key factors driving water use rarely move in a linear fashion. Some of the reasons for this include:

- Economic cycles, economic competitiveness, employment growth, and associated population inflows are extremely difficult to predict as the national and regional economy continues to evolve and change.
- Population and employment growth, even when correctly projected citywide, often may occur in a city neighborhood or district in ways that were not anticipated. Population and employment distribution patterns within Phoenix can be difficult to predict. Resident preferences for different housing types, and their associated ramifications for water use, whether it be single-family homes, townhomes, condominiums, or multifamily developments is hard to ascertain over a long period. While there has been a recent trend toward urban living, it is difficult to know whether this is a short-term trend or a fundamental, long term shift, which adds to the difficulty in developing long range projection scenarios.
- The adoption of water-efficient devices and low water use landscaping has been faster than anticipated, but often at highly variable rates that is not often correlated with population growth and economic activity.

The introduction of new technologies or practices often occurs in a dramatic manner, spurred on by stricter specifications or regulations, reduced costs, cultural change, and innovation. Because of these uncertainties, three water demand scenarios were developed based on plausible futures for the variables described above.

4.3.2 Key Population and Development Assumptions

Three scenarios made up of different assumptions about population and development were derived from State of Arizona and the Maricopa Association of Governments (MAG) projections. These assumptions, called "low", "reference", and "high" were produced by multiplying the State of Arizona's low, medium, and high population projection series for Maricopa County by the percentage of county population allocated by MAG to Phoenix in its projections.[31] The City's sets of assumptions were then allocated to on-project and off-project parts of Phoenix, taking into account both MAG figures and additional information related to development capacity and trends. All three sets of assumptions assume the same growth percentage allocated by MAG to the City of Phoenix. Because only so much land remains for future single-family development, the City's single-family area will likely build out sometime between 2050 and 2070, regardless of the rate of population growth in the metropolitan area and the City. On the other hand, Phoenix has the capacity to accommodate a tremendous amount of multifamily development, so strong population growth residing in high-density housing could have a major impact on future water demand. As a result, the differences in population projections between the "low", "reference," and "high" assumptions are largely due to the relative rate in which multifamily develops.

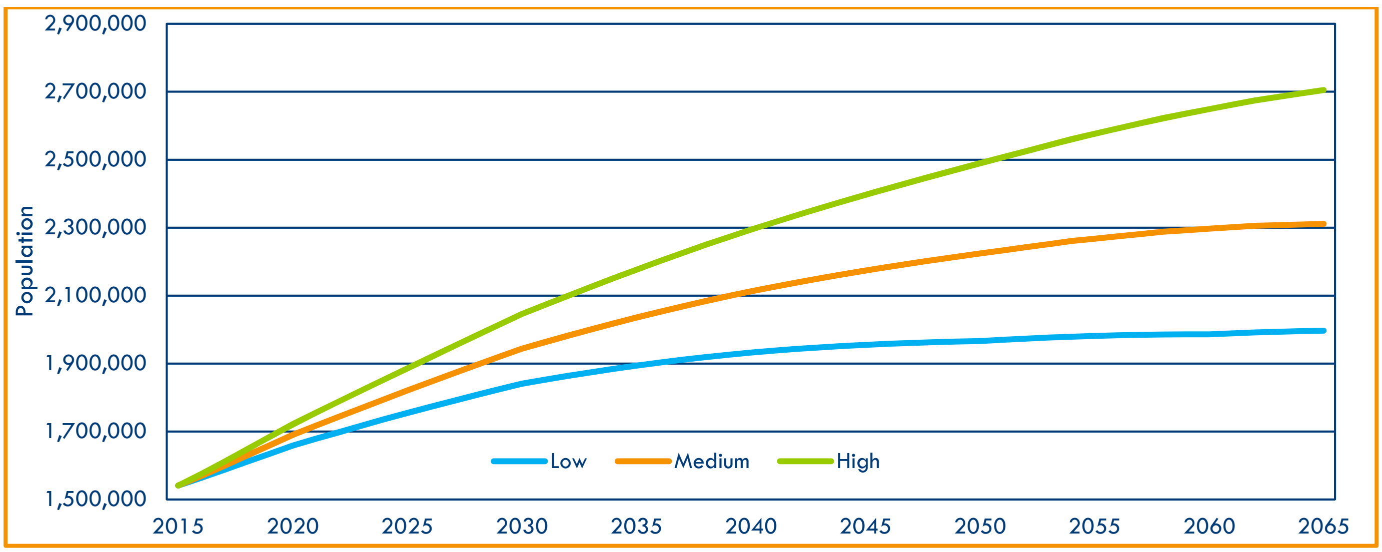


FIGURE 43. POPULATION PROJECTIONS

[31] MAG takes the State control totals for Maricopa and Pinal Counties and then allocates that population growth into subareas based on a sophisticated model that incorporates information about transportation flows and capacity, land development, municipal zoning and general plan maps, and market forces. MAG's models also project the location and quantity of future residential construction and employment growth into subareas.

To some extent the three sets of assumptions correspond roughly with historical precedents. The low trend corresponds with population growth experienced from 2000 to 2015 – a period of relatively slow growth. The high trend, on the other hand, reflects the extremely strong growth that took place in Phoenix from 1970 to 1990. Trends since 2015, especially in terms of single-family housing and commercial development, most closely correspond to the 'low' trend although it appears growth has been accelerating somewhat since 2018. Population and employment change tend to work in long cycles and it is difficult to predict what will take place in the future. While natural increase can be accurately projected many years into the future, Arizona's – and Phoenix's – population growth has always been greatly affected by migration from other states and other countries, so even minor changes in migration rates can have huge implications for Phoenix.

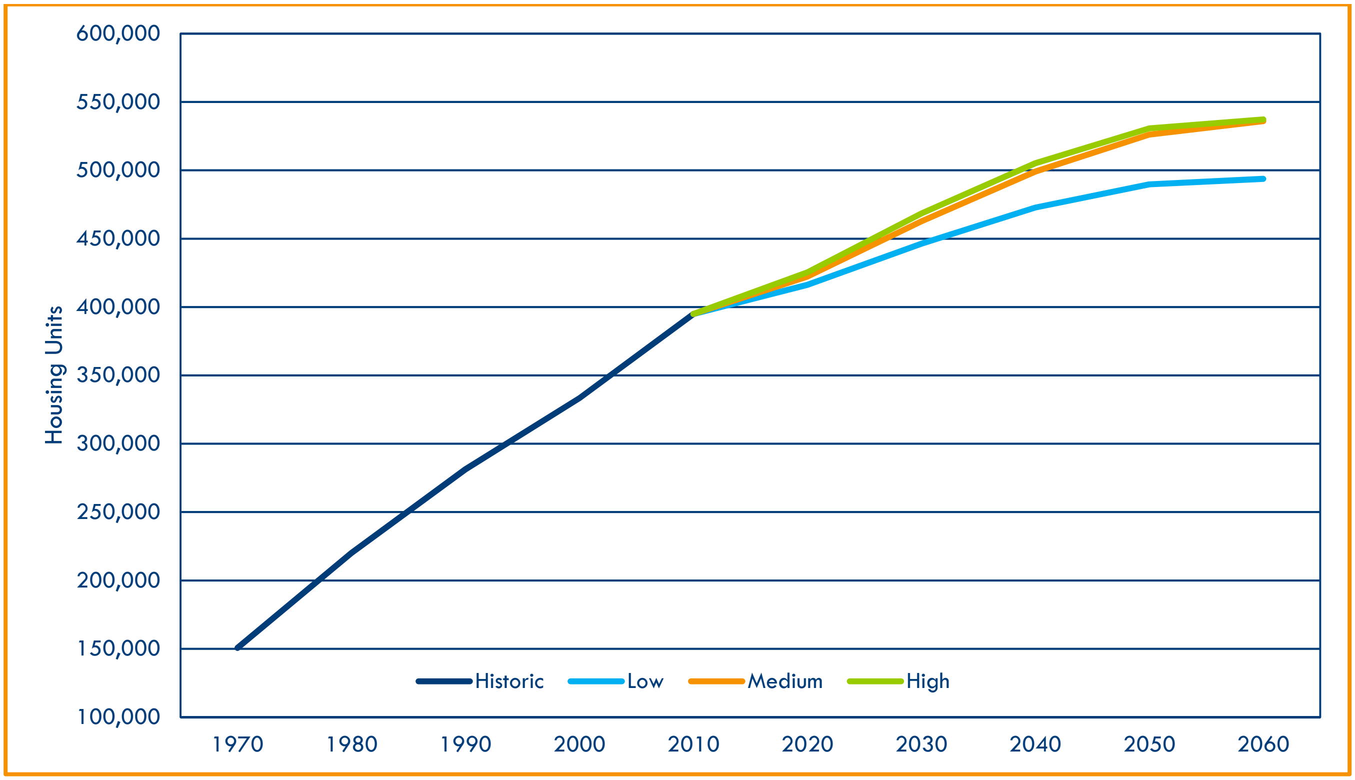


FIGURE 44. SINGLE FAMILY HOUSING UNITS, HISTORIC AND PROJECTIONS

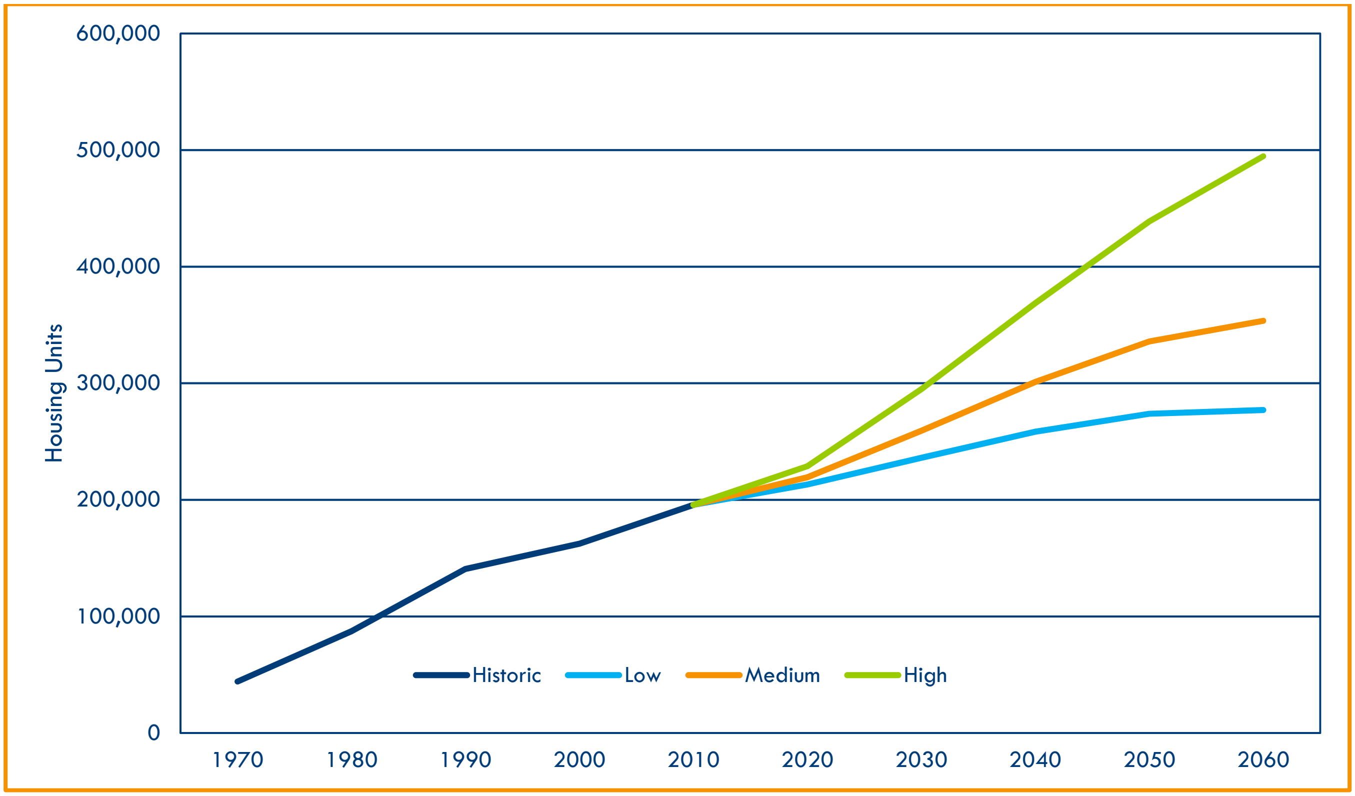


FIGURE 45. MULTIFAMILY UNITS, HISTORIC AND PROJECTIONS

4.3.3 Key Water Use Device and Landscaping Assumptions

Three key water use device and landscaping assumptions were prepared largely using primary data collected by the City, and are referred to as “conservative”, “reference” and “efficient.” The conservative trend assumes the City’s mix of landscaping and associated water use would remain essentially the same for the next fifty years, and that older, less-efficient water using devices would gradually be replaced with newer, more-efficient ones until all devices would be of the type currently available on the market. The conservative trend also assumes that when most devices on the market currently exceed federal and state standards, such as toilets and clothes washers, consumers would continue to favor a mix that would be biased towards less efficient devices. For example, it was assumed that many homes and businesses would continue with or install 1.6 gallon per flush toilet or top-loading washers that use more than 20 gallons per wash, even though more efficient models are already widely available on the market.

The efficient trend assumes that over time residential and commercial landscaping will gradually become more water efficient until 2070, which is challenging given that the City’s research indicates that turf-dominated landscaping currently makes up less than one fifth of the total for single-family homes and many commercial and institutional landscapes rely on desert-adapted vegetation and drip-irrigation systems. The efficient trend assumes that less-efficient devices will be gradually replaced by the most efficient currently available (i.e., by 2070 almost all toilets will be 1.28 gallons per flush or less and almost all clothes washers will be front-loaders using less than 15 gallons per wash). The efficient trend also assumes a large proportion of residents of single and multi-family homes will install and use 1.5 or 1.75 gallon per minute showerheads, a significant change from today, where most residents use two gallons or more per minute while showering. For the Commercial and Industrial sectors, the efficient trend anticipates that many schools, hospitals, office buildings, and retail centers will shift to artificial turf, desert landscaping, or mostly-desert landscaping, and that where irrigation systems are used, multi-zone 'smart controller' drip irrigation systems that only water when weather conditions require it will be utilized. The efficient trend also assumes that by 2070 some cooling towers will be replaced with alternative systems like geothermal, and that those that remain will use less water due to optimized cycles, improved insulation, and reduced internal heat loading (due to more energy-efficient devices).

The reference trend is essentially a middle ground between the conservative trend and the efficient trend by assuming that the trend in water use reductions experienced since 1985 will continue. The reference trend does not include any efficiency improvements that would occur due to new or untested technology. The 'efficient' trend does not assume new technologies will be developed and widely used, but only assumes that the use of currently available technology will become more prevalent. Similarly, because information on the demand for pools is mixed, there are no assumptions relating to the proportion of existing homes with pools.

4.3.4 Combining Sets of Assumptions to Create Demand Scenarios

Given the assumptions described above, numerous combinations and permutations of demand assumptions to create future demand scenarios are possible. However, in order to best encapsulate a distinctive range of possible future water demand without undo complexity, especially considering the existence of two supply scenarios, three water demand projection scenarios are utilized. The sets of assumptions were combined into 3 scenarios: Low Growth/Efficient (Low), Reference (Mid), and High Growth/Conservative (High). "Low Growth" refers to the "low" population projection coupled with the "most efficient" water use, while the "High Growth" scenario partners the "high" population projection with the "least efficient" water use. While these assumptions have been combined for purposes of illustration, this does not mean that growth and efficiency are related. The scenarios were created to demonstrate the lowest and highest levels of demand by coupling disparate assumptions. The combined assumptions for these scenarios are described in general terms in Table 8.

VARIABLE:	LOW GROWTH / MOST EFFICENT	REFERENCE	HIGH GROWTH / LEAST EFFICIENT
General Description / Population	Based on State low projections series; slow and steady population growth consistent with recent trends	Based on Maricopa Association of Government projections (State medium series). Strong population growth consistent with 1970 to 2015 period	Based on State high projection series; very strong population growth with significant growth in Downtown and Central Phoenix. Similar to the 1970 to 2000 period but with added central city densification.
Single Family Development	Slow and steady development in both on and off-project areas - build-out not anticipated until well after 2050. Consumers replace less efficient devices with the most efficient available.	Steady construction in both on and off-project areas (majority in off-project areas) - build-out prior to 2050. Trend of efficiency gains since 1985 continues.	Rapid construction with build-out of on-project areas largely taking place before 2030 and build-out of off-project areas (majority of units) a few decades later. Consumer preference toward compliant, but not the most efficient devices available.
Multifamily Development	Slow and steady development in both on-project and off-project areas. Less efficient devices are replaced with the most efficient available.	Strong multi-family growth in both on and off-project areas. Trend of efficiency gains since 1985 continues.	Very strong multi-family growth in the City's central/on-project leads to a much higher ratio of MF to SF units and continued population increases. Preference toward compliant, but not the most efficient devices available.
Assumed Commercial, Industrial and Institutional Growth	Water use remains proportionately consistent to residential use.	Water use remains proportionately consistent to residential use.	Water use remains proportionately consistent to residential use.

TABLE 8. GENERAL WATER DEMAND PROJECTIONS SCENARIO ASSUMPTIONS

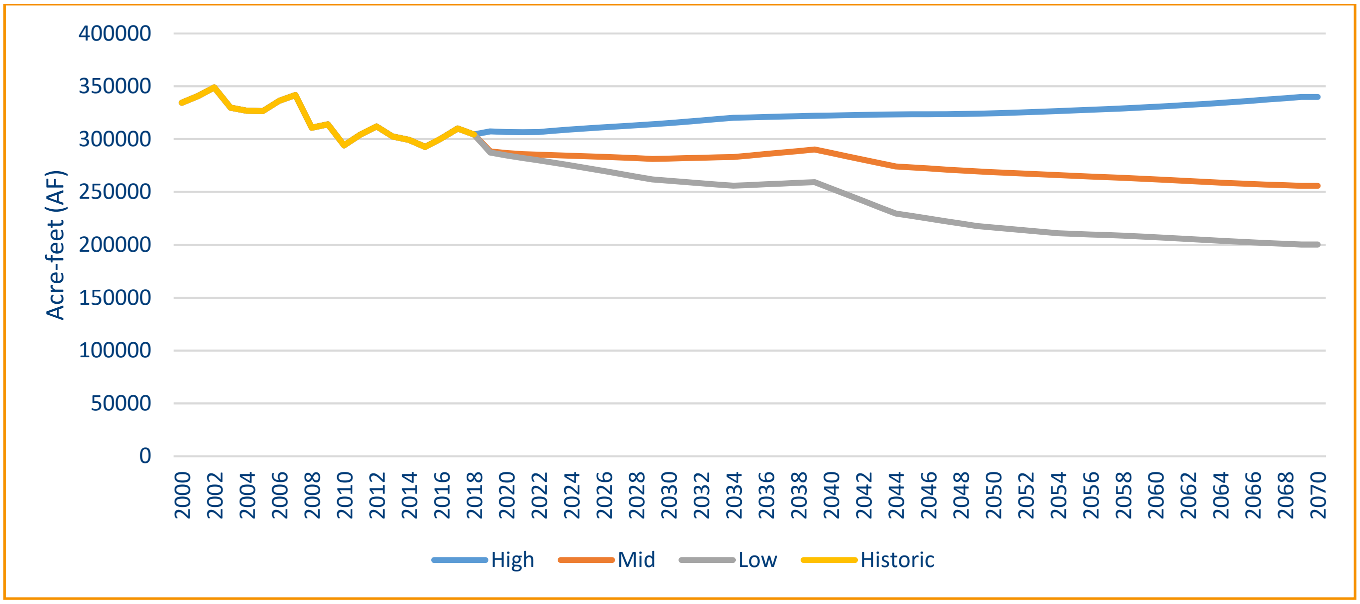


FIGURE 46. WATER DEMAND TREND AND PROJECTION SCENARIOS

Historic water production since 2001 in combination with the three projection scenarios (which have been adjusted to account for system losses) is shown in Figure 46.

4.4 The Supply and Demand Projections: Evaluated Together

4.4.1 Citywide Supply and Demand Projections

Assessing the City's water supply and demands on a citywide level masks some key resource planning issues that occur because different parts of the City have access to different supplies. As explained in Chapter 2, the City serves Salt and Verde River water associated with SRP water rights exclusively to on-project lands. The City serves Colorado River water, groundwater, reclaimed water, and Salt and Verde River waters associated with Phoenix water rights to off-project areas of the City's service area. Just as supplies vary for these two areas of the City, so can water demand and growth. The three water demand scenarios have variable geospatial population and employment growth, and this can affect the proportion of on-project water demand that occurs versus off-project areas. For example, the "high growth" has proportionately higher on-project demand, because it incorporates an assumption that significant development will occur in the central city. For this reason, the demand and supply scenarios that address on-project and off-project portions of the service area are distinct. The projections for these two areas are described below.

4.4.2 On-Project Demand and Supply Projections

The projections for on-project areas of the City do not show any deficit occurring through 2070, regardless of demand or supply scenario (Figure 47). This is largely due to the City's already low per-acre water demand on SRP shareholder lands relative to the SRP allocations available to those lands. Even for the "dry" supply scenario, which models the driest period on the

Salt/Verde system adjusted for lower runoff due to climate change, SRP supplies remain sufficient to meet demands even though they are cut frequently compared to the historic period (seven allocation cuts during the projection period). This is due largely to projected reductions in water demand over time on SRP shareholder lands. Although this land is mostly urbanized, water demand will continue to decline because the remaining lands used for agricultural purposes are projected to mostly convert to municipal and industrial uses by 2070. Agriculture, on a per-acre basis, uses more water than urbanized land, so urbanization acts to reduce overall water demand. Shareholder lands in other cities will see similar water efficiency gains as those in Phoenix (see Chapter 3 for details).

The net effect is that despite reduced runoff and supplies in the "dry" supply scenario, reduced on-project demand largely compensates for or negates the effects on the balance of available supplies.

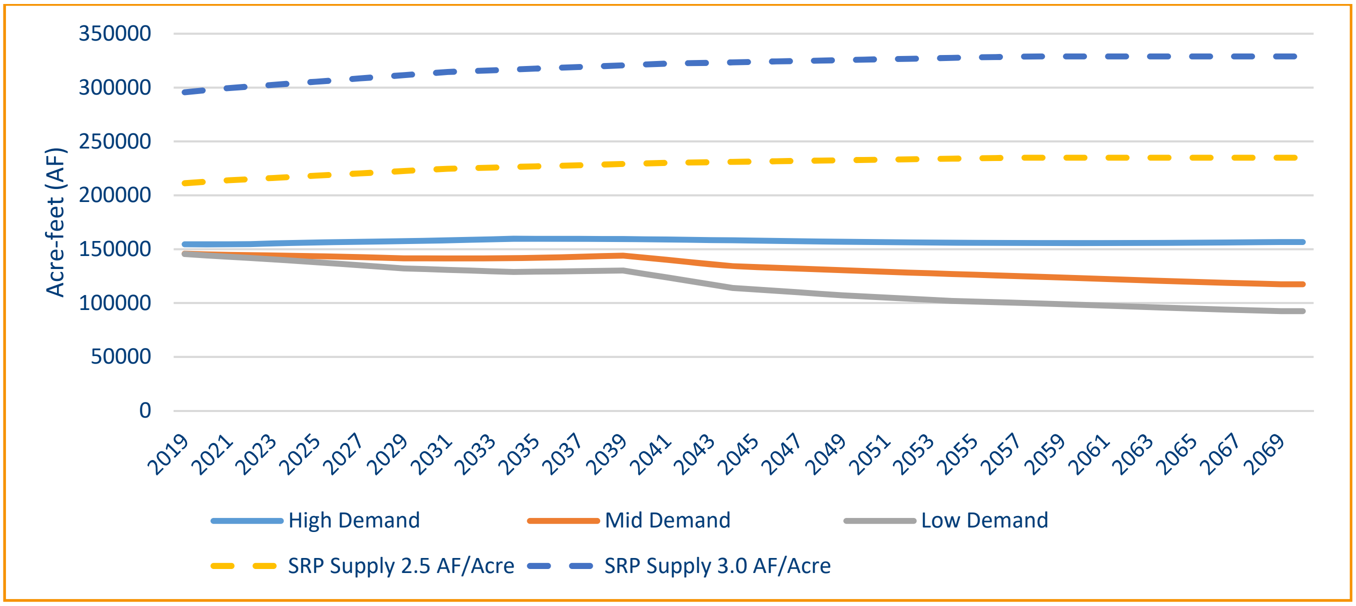


FIGURE 47. ON-PROJECT SUPPLY AND DEMAND PROJECTIONS

4.4.3 Off-Project Demand and Supply Projections

Unlike the on-project areas of the City, significant supply deficits occur when long term, dry conditions with reduced runoff caused by climate change are projected for the off-project areas of the Phoenix service area. This result occurs not only with high growth and conservative water demand, but also with more moderate water demand, which assumes relatively lower population and employment growth and greater water efficiency gains. In addition to Colorado River Supplies, the City can serve certain Salt and Verde River supplies, such as Verde River Gatewater, NCS water, and RID Exchange water in off-project areas of the City. However, movement of these supplies from water treatment plants on the SRP Canal system to areas of north Phoenix is currently limited by distribution system and pump station capacity. Phoenix Water will complete infrastructure improvements in 2023 to move water from the southern to the northern parts of the service area. The additional infrastructure will be essential if there are severe cuts to Colorado River supplies.

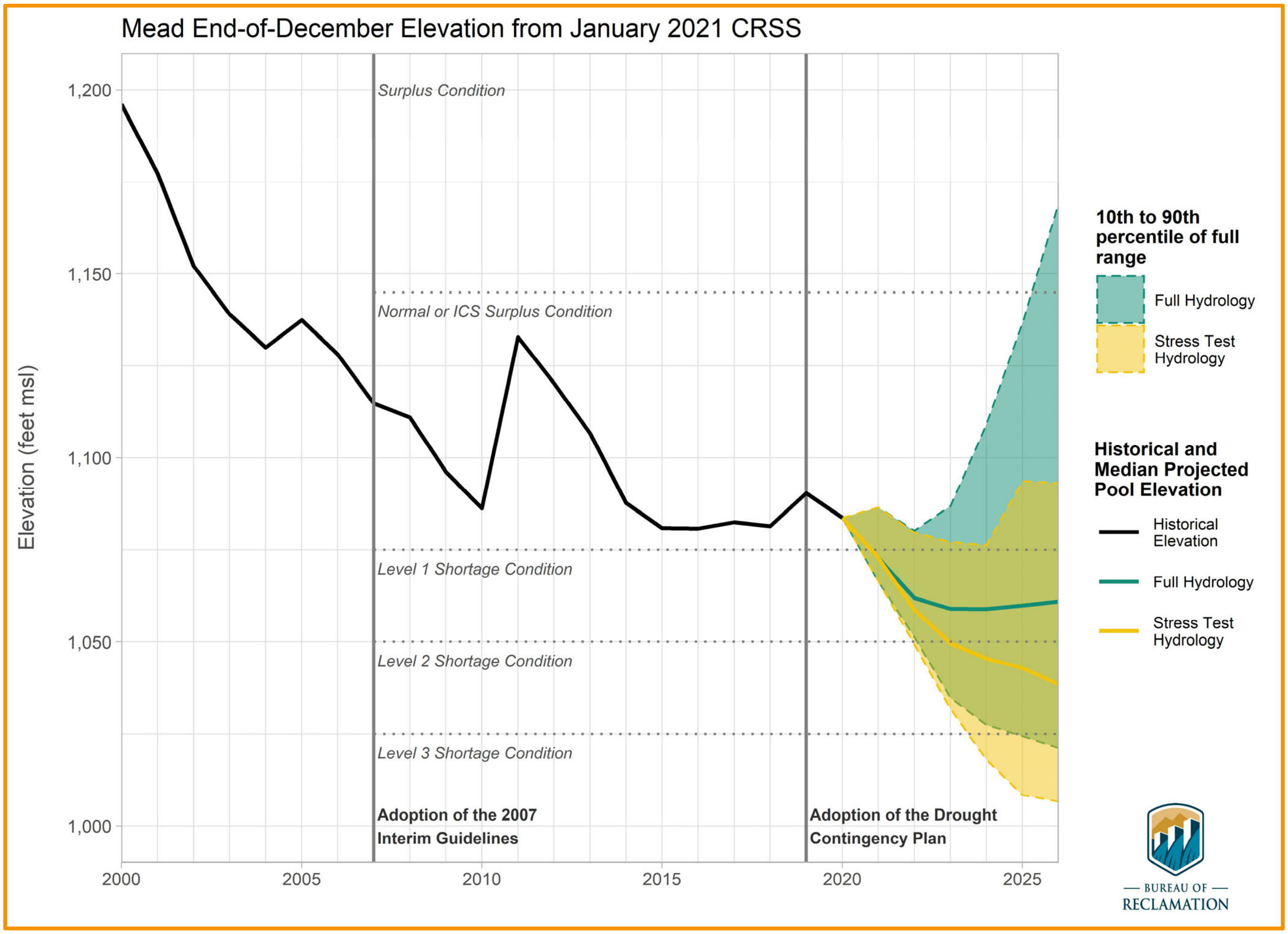


FIGURE 48. LAKE MEAD ELEVATION FORECAST (SOURCE: UNITED STATES BUREAU OF RECLAMATION.)

Figure 48 demonstrates that there is a significant chance for shortages to Colorado River supplies due to the wide range of potential Lake Mead elevations in the near term. In order to plan for adequate water to supply off-project areas within Phoenix, it is necessary to identify the various options to mitigate shortages. These measures can vary, based on both the volume of shortage and the duration. Short term or incremental shortages can be supplemented by using alternative SRP supplies that can legally be delivered to customers City-wide. Conversely, long-term shortages which require sustained mitigation would require other efforts such as demand management, utilizing greater volumes of effluent as a resource, calling exchange agreements with storage partners, or some combination of similar efforts. These strategies are discussed in much more detail in Chapter 5.

The period of greatest uncertainty will be after 2026, the year the LBDCP and the Interim Guidelines both expire. Under existing law, and until further Colorado River operating agreements are reached after 2026, shortage on the Colorado River will be taken first by

Arizona, prior to any other state. Moreover, the ability to precisely forecast the availability of Colorado River supplies after 2026 is extremely difficult, if not impossible. Short range planning that examines scenarios where there is as much a Tier 3 shortage under the LBDCP can be useful. However, if Lake Mead were to continue to fall farther below elevation 1,025’, the quantitative impacts are uncertain.

Significant supply shortages are possible in repeated scenarios where high demand and severe cuts to Colorado River supplies occur steadily through 2070. While unlikely, to the extent the projections assume simultaneous dry conditions on the Salt and Verde Rivers, the resulting shortage also reflects the lack of available Verde River Gatewater, NCS supplies, and RID Exchange supplies that ordinarily would be used to mitigate for the lack of Colorado River supplies delivered by the CAP.

4.5 Conclusions

Based on the modeled scenarios, the City concludes:

- The resiliency of the SRP system protects the on-project areas of the City from water supply shortfalls for the foreseeable future and for decades to come. On the other hand, conditions on the Colorado River are precarious and can worsen quickly. Interim Guidelines and the addition of the Lower Basin Drought Contingency Plan only quantify shortage volumes based on Lake Mead elevations falling to just below 1,025’. There are no further Basin-wide mitigation strategies to address declines in Lake Mead elevation below 1,025’. For the purpose of estimating the effects of extreme shortage to CAP supplies, it is a prudent exercise to examine the measures necessary to fully mitigate the total loss of a CAP supply. While unlikely to occur, using this scenario allows for planning for potential shortfalls when Lake Mead falls below elevation 1,025’.
- On-project supplies are projected to remain ample for Phoenix through 2070, even under a drier climate cycle exacerbated by climate change.
- Off-project supplies appear adequate to meet demand through 2070 if historically average runoff occurs. However, if a long-term dry cycle persists, steady growth and slow increases in water efficiencies could result in shortfall in current supplies. While off-project deficits are largely due to reductions in Colorado River supplies, another significant factor is the sharply reduced availability of Salt and Verde River supplies that can be used off-project. While Phoenix can accumulate over 200,000 AF in NCS and Gatewater supplies, only a portion is available as a reliable renewable supply. The exact reliable annual volume available to replace other off-project supplies has not been established due a lack of systematic use over time.
- There are several key assumptions made regarding Colorado River supply projections that could greatly influence the deficits that have been projected in this plan. For example, the current Colorado River Interim Guidelines and the LBDCP expire in 2026. This plan assumes Arizona will experience comparable shortfalls to those described in the Guidelines and LBDCP. However, additional impacts from climate change or increased demand on the

Colorado River, especially in the Upper Basin, might further exacerbate the difficulty in projecting mitigation needs.

- The highest anticipated service area growth scenario results in the most significant deficits, which would need to be addressed with additional supply development and potentially rigorous demand management.
- The potential for deficit conditions (and the need for additional supplies) is significantly less if demand growth follows a lower trajectory. Low growth coupled with high water efficiency would not result in a supply deficit.

Continued monitoring of supply conditions and demand trends, and periodic reassessment of the assumptions and ranges presented in this chapter, are critical factors in deploying successful mitigation efforts.

CHAPTER 5 – DEFICIT MITIGATION STRATEGIES

A review of the supply and demand projections in Chapter 4 reveals that Phoenix has effectively decoupled population growth from water demand, while also building a resilient and robust water resource portfolio. Though population growth does not have a direct linear correlation with future water needs, projections reveal significant uncertainty in the long-term availability of Phoenix's existing supply sources. On-project areas of Phoenix served by Salt and Verde supplies are projected to have a very low likelihood of shortage, but off-project areas of Phoenix currently served by Colorado River supplies are much more vulnerable to shortages, even for long, protracted periods of time.

Although the risk to Colorado River supplies is known, quantifying the risk or predicting the timing of shortage in the planning period with any precision is nearly impossible. In addition, while Phoenix has vast groundwater resources below its service area, increased groundwater pumping by other Phoenix metro cities caused by shortages in Colorado River supplies may have a significant impact on the long-term availability of groundwater supplies. In the face of this uncertainty, Phoenix must develop a menu of deficit mitigation strategies that can be layered and implemented simultaneously to maintain redundant and ample supplies that can be delivered to all Phoenix Water customers.

Phoenix will consider strategies from three categories to address water supply deficits: system improvements and regional collaboration; demand management; and supply augmentation. The optimal mix of solutions is determined through assessing the volumetric ranges of deficits, lead times for implementation, and the relative cost effectiveness of each strategy. Because of the number of variables, the optimal mix of solutions will likely change over time.

5.1 System Improvements and Regional Collaboration

Phoenix must make the most efficient use of available supplies as prolonged drought and climate change impact renewable water resources. This includes efforts to optimize efficiency in utility management, through infrastructure investment and utilization, reducing system loss within the City's service area, utilizing all available sources of water, and taking actions to protect the respective watersheds. Phoenix will collaborate with regional partners, including other municipal and industrial water users, tribes, and non-governmental organizations to explore emerging strategies to create resiliency that can withstand both short and long-term supply challenges. Phoenix's watershed protection strategy is generally broader in scope, and while source water protection is necessary in both the Salt/Verde River system and Colorado River system, the specific strategies are different.

5.1.1 City Infrastructure Solutions

Phoenix must continue its commitment to infrastructure solutions in the use of available supplies before addressing new opportunities to maintain or augment existing water resources. This requires a rate structure that allows Phoenix Water to proactively maintain over 7,000 miles of pipes as well as other critical infrastructure to provide flexibility and redundancy in moving water throughout the City's service area. Maintaining infrastructure is not only a best practice for a utility serving a major city, it is essential for a city in the desert southwest facing water resource challenges. The rate structure also must support the flexibility to acquire additional water resources or otherwise mitigate the impacts on existing resources caused by drought and climate change. The following projects are examples of the infrastructure commitment necessary to achieve optimum efficiency.

DROUGHT PIPELINE

Phoenix Water is constructing large transmission mains and associated infrastructure ("Drought Pipeline," Figure 49) to move water from the central portion of the City service area to off-project areas in the northern portions of the service area. This is a significant undertaking, but one that provides direct mitigation of the risk of loss to Colorado River supplies delivered through the CAP. In the event supplies delivered through the CAP are severely or completely curtailed, Phoenix will move the volume of water necessary to serve the off-project portions of the City using Gatewater and NCS supplies from the Salt and Verde Rivers, as well as recovered Colorado River supplies previously stored underground within the on-project portions of the City's service area. These supplies are legally available to all portions of the Phoenix service area, but without the infrastructure, the physical use of these supplies in off-project areas is constrained. This necessary infrastructure also supplies much needed operational redundancy and resiliency in all portions of the Phoenix Water system, even during periods when full supplies are available.

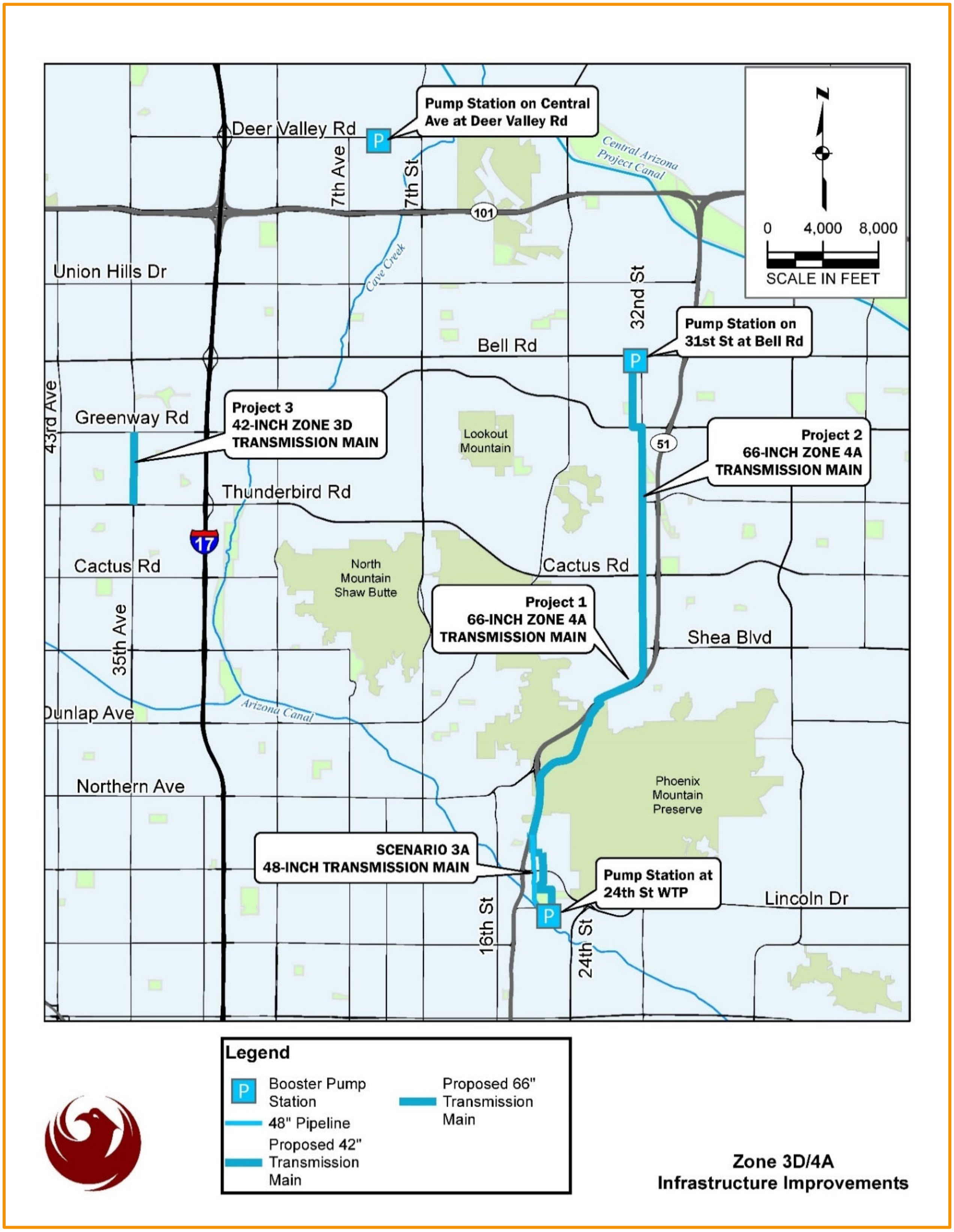


FIGURE 49. DROUGHT PIPELINE PROJECT MAP

WELLFIELD INFRASTRUCTURE

Phoenix is also making substantial investments in wellfield infrastructure to improve resiliency. The initial water system acquired by Phoenix in 1907 pumped brackish and poor-tasting groundwater using shallow wells. Subsequently, Phoenix began treating Verde and Salt River surface water supplies as a better alternative to groundwater. In the 1940s, Phoenix drilled deeper wells about 12 miles east of town and later in off-project lands throughout its service area. With the advent of the 1980 Groundwater Management Act, Phoenix began a period of wellfield reduction to reduce its reliance on groundwater. Contributing factors to the reduction included aging well infrastructure and groundwater contamination. Many of Phoenix's closed wells are in the central portion of the service area and were not replaced or rehabilitated due to their location in aquifers impacted by contamination from industrial chemicals, nitrates from agricultural operations, or naturally occurring arsenic. Phoenix can still treat this water to drinking water standards, but the combination of sustainability concerns about the overuse of groundwater and the aging infrastructure and poor water quality resulted in a shift to renewable surface water supplies.

Phoenix's existing potable water system relies primarily on robust surface water supplies, but groundwater remains a vital component of the water supply portfolio. Currently, Phoenix uses about 22 water production wells to augment supplies, which makes up about 2% of Phoenix's potable water. The wellfield infrastructure has a pumping capacity of 32 MGD, but due to the infrequent use of the existing wellfield, only a 65 percent duty cycle can be assumed. Phoenix can produce about 23,000 AF of groundwater per year (or about 20.6 MGD), but generally, Phoenix operates its wells periodically with a small pump duty to maintain them in good working condition for future operations. For reference, in 2019, Phoenix pumped about 3,744 AF or 1.27% of its total potable supply. This pumping capacity may be increased over time as older wells are replaced or rehabilitated and new wells in off-project areas of the City are installed.

Phoenix will install up to 14 new production wells to develop capacity for future shortages in surface water supplies (Figure 50). These new water supply wells will be in areas advantageous to Phoenix (i.e. parks and City properties) where they can be used to meet off-project water demands. These well sites are strategically located for easy connection to Phoenix's potable water distribution system to convey the groundwater to where it is needed.

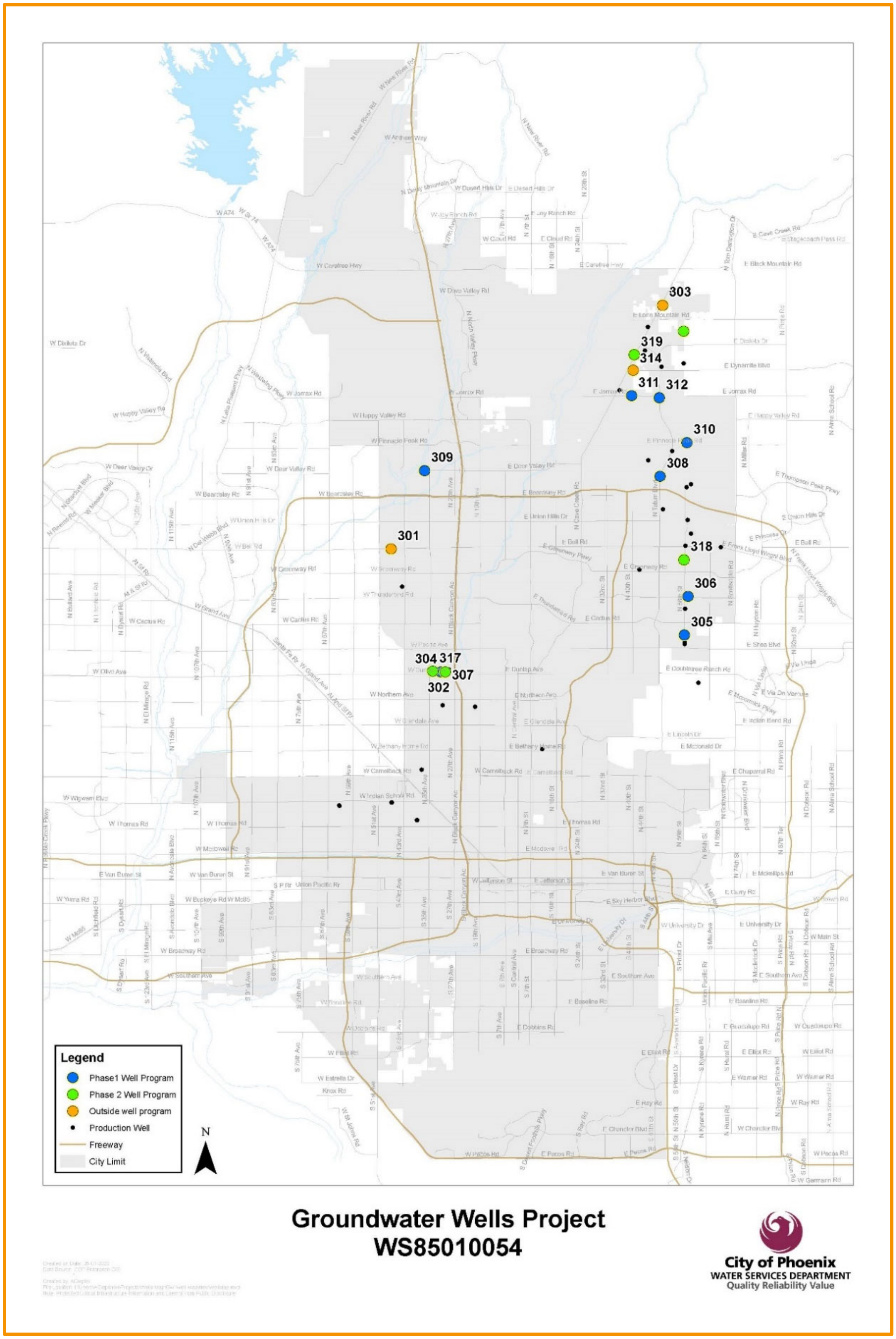


FIGURE 50. PHOENIX WELL PROGRAM

Non-City wells located within Phoenix pose potential physical constraints to increased groundwater pumping by Phoenix due to hydrogeological limitations in the aquifer system. These non-City wells are protected by ADWR's well spacing rules. Well spacing rules are designed to prevent unreasonable damage to surrounding land or other water users in an AMA from a concentration of wells. To address this challenge, Phoenix is permitting some of its new production wells as "replacement wells" to former City production wells that are no longer used. This acceptable approach essentially transfers the pumping right from the closed well to the new well in approximately the same location.

Phoenix is also planning up to 12 new aquifer storage and recovery (ASR) wells to augment those currently in operation. These wells can inject water into the aquifer and pump it out later using the same well. The new ASR wells will be permitted and operated to pump treated surface water into underground aquifers for either annual recovery and/or for long-term storage. Aquifer storage from these wells has several benefits including improving aquifer conditions, improving overall aquifer water quality, and storing excess water for later recovery and use.

The ASR wells will be installed in off-project areas where recharge will be hydrologically connected to the location of future recovery. This provides a physical benefit to the aquifer underlying Phoenix's service area. Much of the recharge is being planned in the Northeast Aquifer, which has experienced noticeable groundwater level declines over time. The ASR wells will inject Colorado River water, treated at the Union Hills Water Treatment Plant, into the aquifer system. Recharging the aquifer in this area is intended to stabilize and possibly reverse the water level decline trends. Other ASR wells are planned for the Deer Valley area of north Phoenix where New Conservation Space (NCS) supplies will be treated at the Deer Valley Water Treatment Plant before injection into the aquifer system.

By combining pumping from the existing wellfield, the revitalized (expanded) wellfield, and the new ASR wells, Phoenix's water production from groundwater sources could be as much as 61,000 AF/yr, equivalent to about 54 MGD. This larger pumping capacity provides greater flexibility in utilizing groundwater supplies in times of severe drought or when unforeseen situations cause stress to the water delivery system.

Reducing water loss within the utility system is another incremental step in mitigating supply deficits. Whether the loss is through leaks and breaks in infrastructure or a lack of metering or accounting (non-revenue water), understanding the ultimate disposition of water in the distribution system and reducing the percentage of loss is important, especially during periods of supply reduction. The State of Arizona dictates that municipal utilities within AMAs maintain a rolling 3-year average water loss of less than 10% of water produced.[32] Phoenix Water complies with that requirement with an average of 9.49% as of the end of 2019. Reducing the loss percentage by 1 to 2 percent demonstrates a commitment to efficiency and conservation and offers opportunities to review non-revenue water in a way that could slightly enhance

[32] Third Management Plan, Phoenix Active Management Area, Section 5-113(1).

supply. Phoenix Water is developing a team with additional training to provide a more systematic and holistic approach to lost and unaccounted water.

5.1.2 NCS and Gatewater Supplies

The City of Phoenix has surface water storage accounts on the Salt and Verde Rivers, independent of water rights associated with the Salt River Project, that can be used to serve customers anywhere in the service area or stored underground for future recovery. New Conservation Space (NCS) water, as more thoroughly described in Chapter 2, is associated with the enlarged Roosevelt Dam on the Salt River, and Gatewater is associated with control gates the City constructed on Horseshoe Reservoir on the Verde River. There are few restrictions to where and when NCS water and Gatewater can be used. Available volumes can vary from year to year based largely on precipitation (snowpack) and runoff (snowmelt) events on the Salt and Verde Watersheds. NCS storage credits are not subject to spill, while Gatewater credits stored in the Salt River System are subject to spill. Both are subject to evaporative losses.

To date, Phoenix has used some of these supplies for off-project deliveries in limited locations. However, in anticipation of shortage conditions on the Colorado River, Phoenix must develop specific strategies for utilizing NCS and Gatewater supplies that consider the annual and seasonal limitations of these supplies. Infrastructure to move these volumes to the northern portions of the City vulnerable to Colorado River shortages is already under construction.

At the end of 2020, Phoenix had approximately 136,000 AF of NCS storage credits and 67,363 AF of Gatewater storage credits.

5.1.3 Reclaimed Water Supplies from 91st Avenue and 23rd Avenue WWTPs

Reclaimed water is a relatively firm and stable supply that can mitigate water supply shortages. Analyses of historic City data reveals that wastewater flows have been relatively stable relative to water production in Phoenix. Approximately 42 percent of water that is produced for delivery returns to wastewater treatment and reclamation facilities. The ratio of wastewater generated to water produced has remained relatively stable despite changes in indoor water use efficiency and landscaping preferences throughout Phoenix since 1990. Reclaimed supplies (as a percentage of potable water delivered) are projected to remain relatively flat for the medium growth scenario through 2065.

Currently, more than 90 percent of the reclaimed water generated by the 91st Avenue WWTP is reused for industrial cooling at the Palo Verde Nuclear Generating Station; farming at the BIC; and habitat enhancement and treatment at Tres Rios Wetland. Although the agreement with the Palo Verde Nuclear Generating Station expires in 2050, which is within this plan's 2065 time horizon, for planning purposes this commitment is assumed to continue beyond 2050. Any change in use of the reclaimed water from the 91st Avenue WWTP would require the consensus of the SROG cities of Glendale, Mesa, Phoenix, Scottsdale and Tempe, and not all the reclaimed water would be available for use by Phoenix. In addition to the committed volumes, there is a small volume of treated effluent discharged through the Tres Rios Wetland that Phoenix will quantify and evaluate as a potential water resource through exchange with a third party, or some other method of reuse.

FIGURE 51. TRES RIOS WETLANDS, CITY OF PHOENIX.

Reclaimed water from the 23rd Avenue WWTP is primarily used in a three-way agreement with SRP and RID that exchanges up to 30,000 AF of reclaimed water for 20,000 AF of surface water available to Phoenix for off-project potable uses. The term of the exchange agreement ends when RID irrigation needs are reduced to 2,000 acres or less of agricultural land.[33] As a point of reference, in 2020 RID provided irrigation water to over 25,000 acres in Maricopa County. All annual volumes of effluent that exceed 30,000 from 23rd Ave WWTP are stored by Phoenix in the RID GSF as LTSCs for future recovery.

To the extent reclaimed water from 91st Avenue and 23rd Avenue WWTPs is available for additional methods of reuse, there are challenges to incorporating those volumes into the supply portfolio. Current demands for reclaimed water highly fluctuate throughout the year. For example, reactor cooling needs at the Palo Verde Nuclear Generating Station peak in the hotter, summer months, whereas the lowest demand occurs in winter. Another significant challenge is the location of the supply. The 91st Avenue WWTP in far southwest Phoenix, is not well suited for advanced treatment and distribution of reclaimed water because it sits at a lower elevation

[33] 2020 Supplemental Agreement Among Roosevelt Irrigation District, Salt River Project Agricultural Improvement and Power District, Salt River Valley Water Users' Association, and the United States of America, August 13, 2020.

than most of the City's service area. Moving reclaimed water from 91st Avenue WWTP for use within the service area would involve extensive and costly distribution and storage infrastructure, as well as substantial energy costs to pump the supply to needed areas within Phoenix. This is one of many reasons Phoenix is re-opening its Cave Creek Reclamation Plant (discussed below), because it is in an area in which reuse is more cost-effectively achieved.

Instead of increasing Phoenix's use of available reclaimed water from 91st Avenue and 23rd Avenue WWTPs, Phoenix could exchange the reclaimed water with other water users in return for other supplies delivered to more advantageous locations within the Phoenix service area. This model currently works well in the three-way exchange with Phoenix, RID, and SRP. Long-term storage of reclaimed supplies underground for future recovery is another option. However, access to underground storage facilities is limited near the 91st Avenue WWTP because it is located adjacent to an area of the Salt River designated as a waterlogged area with shallow groundwater levels. Permitting a new underground storage facility or even managed recharge involving Tres Rios and the current discharge to the Salt River could prove very difficult. Finally, there is limited land available near the 23rd Avenue WWTP for underground storage and the current environmental contamination of the aquifers would likely preclude permitting of a recharge facility.

5.1.4 Reclaimed Water Supplies from Cave Creek Reclamation Plant

Prior to its closing in 2009, reclaimed water from the Cave Creek Water Reclamation Plant (CCWRP) was delivered through a dedicated system for landscape watering at facilities in northeast Phoenix (see Chapter 2 for further details). However, emerging challenges to existing off-project supplies and the need to augment those supplies in a growing portion of the service area has created an incentive for Phoenix to consider new ways to use reclaimed water from CCWRP. The best alternative to augmenting available supplies in off-project areas of Phoenix may be reopening CCWRP as an Advanced Reclaimed Water Treatment Facility, capable of producing a quality of water for direct potable reuse.

Direct potable reuse (DPR) is the introduction of reclaimed water into a drinking water plant.[34] Arizona has long been a leader in water reuse, and in 2018 the State adopted rules to permit DPR of recycled water.[35] Advanced water treatment includes a sequence of technologies such as ultrafiltration, reverse osmosis, advance oxidation, and use of granular activated carbon, in addition to state-of-the-art, real-time monitoring of the treatment processes and the quality of the finished water product. Although the capital costs for such water treatment processes will

[34] 2017 Potable Reuse Compendium, United States Environmental Protection Agency, Chapter 1.1.

[35] Arizona Administrative Code, R18-9-E701.

be significant, this opportunity expands the array of strategies that could be implemented by Phoenix, especially in off-project areas.

Once Phoenix re-opens CCWRP and retrofits it with advance water treatment technology, this supply could be blended with potable supplies from the nearby Union Hills Water Treatment Plant to mitigate shortages in Colorado River supplies. Additionally, the recycled water could be stored underground in the aquifer or blended with other supplies for subsequent potable use.

Further development of strategies to increase future uses of reclaimed water will be relatively complex due to the factors discussed above. A plan to examine future uses of reclaimed water should be developed to incorporate long-term objectives for using uncommitted reclaimed water as a potable supply or in exchange for other available supplies.

FIGURE 52. CAVE CREEK WATER RECLAMATION PLANT, CITY OF PHOENIX

When contemplating a strategic framework of supply mitigation, all near term projects could be framed with reuse in mind, thus reducing the potential for stranded assets. For example, Phoenix should consider upgrades to transmission lines and treatment facilities, including regional collaboration, for future decades to implement potable blending strategies or distribution of potable recycled water after treatment through an advanced water treatment facility. Determining which strategies are the most cost-effective in various time frames will involve a comprehensive and complex assessment of opportunities and challenges, and periodic reevaluation will be needed.

5.1.5 Regional Response Solutions

Phoenix must consider regional implications when choosing deficit mitigation strategies. Phoenix is the largest of ten municipalities in the Valley that relies on SRP supplies for a portion of its renewable water supplies. By 2044, Phoenix's CAP subcontract will represent almost 23 percent of the total M&I-priority Colorado River water delivered in Central Arizona. As previously discussed in Chapter 4, because Phoenix enjoys some of the most senior rights in the SRP system, the impacts of drought and climate change in the SRP system do not pose a supply risk to the City. However, not all municipalities share the same access to high priority supplies. Other water utilities have variable portfolios of SRP and CAP supplies, groundwater, and stored water (long-term storage credits).

FIGURE 53. SRP CANAL

Shortage on one or more of the watershed systems serving the Phoenix metropolitan area will have varied consequences for water providers. Because all municipal water providers in the Phoenix AMA have access to groundwater, cities may use it to replace surface water supplies lost during shortage conditions. A significant increase in groundwater pumping in the Phoenix AMA could result in groundwater mining (a failure to replenish finite groundwater supplies), which could have serious long-term impacts to Phoenix and surrounding communities. Specifically, groundwater pumping by water providers in the same groundwater sub-basins shared with Phoenix may have adverse impacts on the ability of Phoenix to maintain a robust and resilient groundwater supply portfolio during significant shortage events. In the face of this shared risk, it is important that Phoenix not only engage in infrastructure investments that improve its operational efficiency, but also look for opportunities to secondarily increase the resiliency of its neighboring water systems.

As water supply and infrastructure costs continue to escalate, more cost-effective and efficient regional strategies to reduce shortage risks may be more dependable and cost-effective than a “go-it-alone” approach. Establishing regional strategies well in advance of shortage conditions is paramount in overcoming political, financial, logistical, and legal challenges that may occur in the event some entities are more significantly affected than others. As these solutions are developed, complexities involving existing water rights, contracts, and other legal constraints must be addressed. City actions are likely to include assessing relative benefits and vulnerabilities in participating in regional solutions as well as advocating for and participating in regional dialogue and initiatives that seek practical long-term solutions that maximize benefits and protect the Valley’s economy during shortage events. Phoenix will need to evaluate the costs and benefits of cooperative projects on a case-by-case basis to ensure its interests are commensurately served.

Phoenix has already demonstrated an ability to collaborate with regional partners to achieve efficiencies. Examples of existing collaborative partnerships include agreements between Phoenix and the City of Avondale (Avondale) to “wheel” Avondale’s CAP supplies through the City’s water treatment and distribution system to an interconnect at Avondale’s border. In a separate agreement, Phoenix stores some of its Colorado River supplies in Avondale’s underground storage facility for recovery and exchange with Avondale’s CAP supplies during times of shortage. Capitalizing on the relative strengths of each utility’s infrastructure provides benefits to both entities. Phoenix has a similar agreement for underground storage with Tucson Water that allows Phoenix to store large volumes of Colorado River supplies currently available for exchange during shortage with Tucson's substantial CAP subcontract. Phoenix also has individual agreements with Tolleson, EPCOR Water and Cave Creek that increase the operational efficiencies of both partners.

There are many more opportunities for regional collaboration to maximize the beneficial use of available water, but the challenges of this type of mitigation strategy are time and resources. Devoting resources to develop long-range collaborations, especially when it involves capital for infrastructure, can be daunting. Nevertheless, opportunities are still available for cooperation among water users, including construction, operation and/or maintenance of regional infrastructure such as underground storage facilities; advanced water treatment plants for direct potable reuse and desalting of brackish groundwater; and conveyance infrastructure.

Regional partnerships also can resolve some problems caused by flawed groundwater management policies. One example is the problem of "hydrologic disconnect" in which water providers store water underground in one location and recover or pump it from another location that has no hydrologic connection to the aquifer where the water was stored. This practice could result in limitations to the physical availability of groundwater in certain areas. Regional collaborations can facilitate systematic, conjunctive groundwater pumping that maintains physical availability and quality of groundwater. Exchanges of long-term storage credits to promote recovery of credits in the geographic area where the water was stored may prove invaluable during prolonged drought or extreme shortage of surface water supplies. Phoenix should strive to create these types of arrangements with municipal water providers, private water companies, tribal communities, and wholesale water providers to achieve sustainable groundwater use during shortage.

Phoenix is working with a group of interested water stakeholders to create an Arizona Water Clearinghouse (Clearinghouse) to further advance opportunities for regional collaboration. By fostering and facilitating collaboration among water users, the Clearinghouse could increase the resiliency and sustainability of the region. Phoenix received a grant from the United States Bureau of Reclamation WaterSmart Water Marketing program to begin the process of introducing and socializing these types of collaborations. Phoenix anticipates that a prototype technology tool and report will be available by mid-2022, with possible implementation of the Clearinghouse to follow.

5.1.6 Watershed Protection – Colorado River Basin

Declining elevations in both Lake Mead and Lake Powell pose significant risk to Phoenix's Colorado River supplies. The Lower Basin states (Arizona, California, and Nevada) developed mechanisms in the 2007 Interim Guidelines for Operation of Lake Powell and Lake Mead to protect volumes voluntarily forborne by Colorado River users from being used by other users to encourage conservation in Lake Mead and Lake Powell. One program that has been in use since 2014 is System Conservation. System Conservation allows users to voluntarily forebear water that would have otherwise been used and leave it in Lake Mead or Lake Powell to provide conservation volumes. The user must be able to verify the conservation activities, and the water cannot be recovered in the future by any user, including the one that created the System Conservation volumes.

The 2014 Pilot System Conservation Program was administered by BOR in all Basin States and funded among BOR, CAWCD, the Southern Nevada Water Authority (SNWA), Denver Water and the Metropolitan Water District of Southern California (MWD). During the program's operation through 2019, other third-party funders, including the Walton Family Foundation contributed additional resources to the program. In addition to the Pilot System Conservation Program, Arizona, Nevada, California, and BOR executed a Lower Basin Memorandum of Understanding that allowed additional system compensation in Lake Mead. In 2017, Phoenix partnered with the State of Arizona, the United States Bureau of Reclamation and the Walton Family Foundation to fund the creation of 40,000 AF of system conservation by the Gila River Indian Community. In addition, Phoenix's storage of a portion of its Colorado River water in Tucson aquifers as part of the Phoenix/Tucson exchange has facilitated Tucson's creation of a similar volume of system conservation with the assistance of CAWCD. In all, the Pilot Program in the Lower Basin is expected to create 175,347 AF of system conservation in Lake Mead by 2035.[36] While at least one of the Pilot Program projects will continue through 2035, as of the end of 2019, additional funding opportunities and project proposals are not anticipated as part of the Pilot Program. However, Phoenix supports a renewed effort among the Basin partners to create a permanent Basin-wide system conservation program that includes a specific Arizona component. Ideally, an Arizona system conservation program would coordinate Colorado River users throughout Arizona and the Basin to proactively set goals to create ongoing compensated and uncompensated system conservation projects to benefit the Colorado River Basin by raising the elevations in both Lake Mead and Lake Powell. Optimally, this type of program will be part of the revised operational guidelines for Lake Mead and Lake Powell in 2026.

In addition to system conservation, the Interim Guidelines created opportunities for certain Colorado River contractors to store Colorado River water in Lake Mead as Intentionally Created Surplus (ICS). ICS is different from system conservation in that water conserved as ICS can be recovered later by the party that stored it. Under the Interim Guidelines and the subsequent Drought Contingency Plan, ICS withdrawal has some limitations designed to protect critical Lake Mead elevations. While Phoenix currently cannot directly participate in the creation of ICS with its own entitlement, it is possible that it could facilitate eligible federal contractors to create ICS volumes, especially tribal contractors. In this way, Phoenix's participation in ICS could increase storage volumes in Lake Mead and forestall shortage reductions. In addition, through participation in ICS creation with partners, Phoenix may be able to acquire additional volumes of Colorado River water stored in Lake Mead for future needs.

[36] Pilot System Conservation Program (Pilot Program), United States Bureau of Reclamation Lower Colorado Region (https://www.usbr.gov/lc/region/programs/PilotSysConsProg/pilotsystem.html).

FIGURE 54. LAKE MEAD & HOOVER DAM

Because of potential adverse impacts to Lake Mead from withdrawal of ICS volumes, ICS as a conservation tool may not be as desirable as system conservation, which can never be withdrawn. However, like system conservation, as opportunities to create ICS become available, Phoenix's participation as a facilitating entity advances its goal to increase Colorado River water storage, with the additional benefit of potentially creating a new high priority water source in the Colorado River. It was with this type of facilitation in mind that the Phoenix City Council in 2014 created the Colorado River Resiliency Fund, a permanent component of the Phoenix Water Services Department Capital Improvement Program. It is designed to fund various resiliency efforts to help protect the City against water shortage events, including additional Colorado River water storage, expansion of the City's Aquifer Storage and Recovery Well Program, facilitation of system conservation and ICS, and watershed protection efforts in the Colorado, Salt, and Verde Rivers.

5.1.7 Watershed Protection – Salt/Verde River System

Phoenix's Salt/Verde River supplies are more resilient than those in the Colorado River system. However, long-term drought and climate change have increased the incidence of catastrophic wildfire in the headwaters of the Salt and Verde Rivers. The sediment runoff from these wildfires has impacted water quality treatment costs at Phoenix water treatment facilities on the

SRP system and reduces storage capacity in existing Salt and Verde reservoirs, reducing the overall resiliency of the water resource. In an effort to mitigate the impact of catastrophic wildfire on the Salt and Verde watersheds, Phoenix entered into an agreement with the National Forest Foundation (NAFF), with a funding commitment of $200,000 a year. This funding facilitates projects for forest restoration and watershed health in the Salt and Verde watersheds to: (1) prevent further water quality degradation from post-fire runoff; and (2) reduce the risks of additional catastrophic wildfires. The scale of the problem is significant due to the critical overgrown nature of the forests in Arizona and the federal regulatory oversight to conduct forest thinning in national forests. However, NAFF has enjoyed remarkable successes with modest projects, and Phoenix sees the potential for a long-term partnership in the future.

FIGURE 55. RAINSTORM IN THE VERDE VALLEY NEAR SEDONA, AZ

Similarly, The Nature Conservancy (TNC) has created a Salt and Verde Alliance to fund watershed projects in the Salt and Verde River systems that promote improved water quality and increase river flows. In addition to forest thinning projects and creation of industry to support long-term forest restoration, many of TNC's innovative efforts promote conservation and efficiencies from water users in the Verde Valley. Under its agreement with TNC, Phoenix provides $150,000 each year to fund projects to mitigate risk factors to water quality in the Salt and Verde watersheds.

These types of source water protection efforts are broader than just Phoenix water supplies. The challenge of prolonged drought and climate change requires collaboration among water users to yield the conservation impacts required to address the scope of the challenge. It is difficult to quantify in acre feet the exact impacts of these mitigation strategies, but it is a necessary investment in the long-term sustainability of Phoenix's surface water supplies. As the City directs resources through the Colorado River Resiliency Fund to the critical issue of watershed health, it has the effect of incentivizing other municipalities and private industry to do the same. Both NFF and TNC have seen additional financial supporters join their forest restoration efforts since Phoenix initially committed its funding, so the overall public awareness and funding efforts are improved.

5.2 Demand Management

Phoenix Water operates in a desert environment, recognizes the finite nature of water resources and uses water in ways that reflect that understanding. Phoenix customers have embraced the concept of water conservation – consciously choosing to use less water – as an essential cultural norm in the Southwest. However, in planning for future scenarios of shortage, it may be insufficient to generally encourage water conservation, or to rely upon the voluntary goodwill of customers to use less water. Demand management is a more precise way to intentionally influence the use of water, by including techniques to encourage water conservation and strategies for creating efficiencies in water use. Targeted initiatives can be utilized to achieve more exact results in reductions of water use, both in the short-term as well as permanent changes. Demand management strategies must be carefully studied in advance so the resulting reductions and efficiencies can be used quantitatively to produce the desired results in the requisite amount of time and be effective in mitigating supply deficiencies.

5.2.1 Long-Term Efficiency Improvements

The practice of adopting new technologies that improve water efficiency and reduce water use in Phoenix has been occurring for decades. Low-flow toilets, showerheads, and faucets have been incorporated into newer construction, and additional “smart” technologies, including smart irrigation controllers, have given customers new insights into water use, resulting in increasing efficiencies. While further advancements will likely occur in the future, there are still existing technological improvements that could be implemented in many parts of the City. Additional demand management studies are underway to determine what City actions are necessary to inform, persuade or compel implementation of these available technologies, and when and how this should be done. Strategies encouraging the additional use of technology must convince customers that the new water efficient device will be as productive in its designed use as the device it is replacing, whether that device is a high-efficiency dishwasher or complex manufacturing equipment. The City must also determine the relevant factors that influence the choice to implement new technology, as the cost of water is seldom the primary consideration. Finally, adoption of technology advances tends to be gradual. The City must determine the optimal combination of information, incentives, or requirements necessary to achieve the strategic benefits of improved water technologies in the timeframe necessary to accomplish the water use reduction.

Other long-term water use reductions have been achieved in Phoenix by influencing customer preferences. This shift in preferences is evident in the change in the residential and commercial landscapes beginning in the 1990s. Many customers changed their landscapes from high water use vegetation like grass and exotic, non-native flowers and fruit trees to more water-efficient desert xeriscape or partial desert elements like native plants, imported desert-adapted plants, gravel, and rock. In the 1980s, most single-family homes had turf in both front and back yards, but now the majority of single-family units have either mostly desert landscapes (majority gravel/rock with some trees, shrubs and cactus) or partial desert landscapes (majority gravel/rock with patches of grass and/or trees and shrubs). This change has been largely due to Phoenix's adoption of a rate structure in which water costs more in the summer and initiatives by Phoenix, the Arizona Municipal Water Users Association, the State, and other agencies to provide 'how-to' materials and public workshops for customers, to promote native plant stocking at nurseries, to advertise and promote desert landscapes, and to require low water use landscaping in public rights-of-way. More recently, efforts to persuade residents to consider efficient water use as part of a desert lifestyle have included a long-term advertising and conservation campaign by Phoenix Water to bring awareness to its customers about the persistent need for water conservation consciousness.

It is notable that Phoenix has been able to achieve quantifiable conservation results without incentive programs that provide cash rebates or subsidies. To date, continued education and outreach efforts are sustaining the trend toward efficiency. As demonstrated below (Figure 56) and noted elsewhere, Phoenix has reduced its gallons-per-capita-per-day (GPCD) by 30% over the last 20 years, despite an increase of over 400,000 customers.

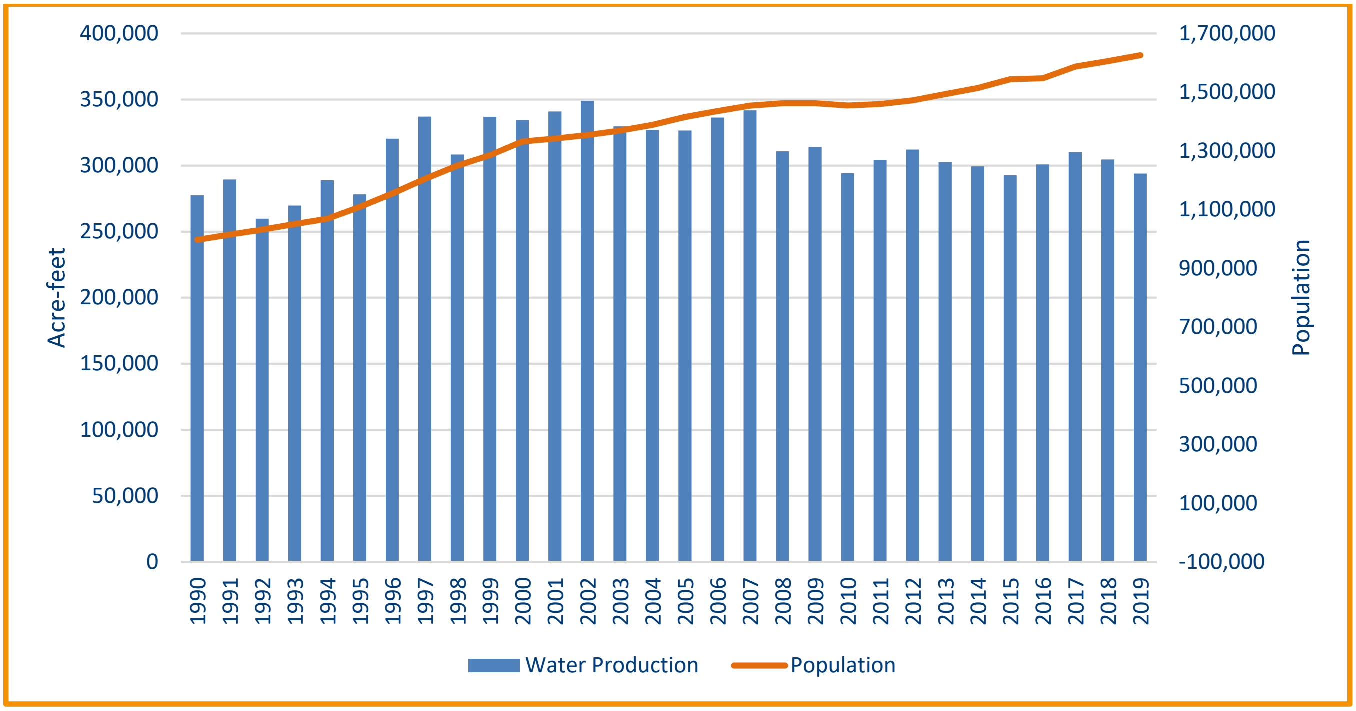


FIGURE 56. PHOENIX WATER PRODUCTION VS POPULATION GROWTH, 1990-2019

As the City considers future efforts to encourage water efficiency and conservation, it is important to differentiate between behavioral and preferential changes associated with long-term cultural change versus those associated with more immediate targeted incentivized reductions in water use. In Phoenix, and in most of Arizona, changes in landscapes and outdoor water use evolved over decades, whereas in other places like California, Colorado, Texas, and Australia, severe droughts led to major publicity campaigns, regulatory actions, incentive programs, and significantly higher water rates devised to quickly decrease water use through behavioral changes. Whether the short-term response is prompted by a financial incentive, or a regulatory requirement based on an emergency situation, sometimes it can result in a “rebound” effect when the financial incentives are exhausted, or the emergency situation ends and users wish to return to more “normal” water use patterns. In contrast, long-term reductions in outdoor water use in Phoenix reflect widespread cultural changes of what is perceived as being acceptable or even normal in terms of residential and commercial landscapes. These changes are the result of sustained outreach campaigns and advertising, and sensitivity to environmental issues promoted by the national media and school curriculums. The challenge is to develop programs for short-term demand management that also produce lasting changes in water use.

As described in Chapter 3, Phoenix and most other North American cities have experienced long-term trends of progressive water use efficiency and ongoing reductions in per-capita water use. Efficiency gains are primarily associated with improved technologies or shifts in water use behaviors. These trends will likely continue for decades, even without City action or stimulus. However, in the face of prolonged, severe shortage, Phoenix should proactively develop strategies to reduce per-capita demand to levels lower than those that would be achieved passively over time. This was the rationale of the 2019 Phoenix Water Conservation Ad Hoc Committee. This committee of informed citizens, local water leaders, and City Council members created a “water metric” to reduce total GPCD from 169 in 2019 to 155 by 2030, using specific initiatives to encourage and incentivize water conservation. The following section describes the recommendations and strategies adopted by the Committee, and subsequently the Phoenix City Council, to advance conservation through 2030.

5.2.2 Strategies for Achieving Additional Supplies through Demand Management

Many of the recommendations adopted by the Ad Hoc Committee reflect established strategies that have been successful in municipalities nationwide but are certainly not exhaustive. The recommendations are listed here in categories that reflect broader conservation strategies but do not reflect the full spectrum of activities applicable to a strategy. However, they are the specific recommendations of the Phoenix City Council in 2019. If more demand management is necessary to balance available supply and demand, Phoenix Water likely would implement additional actions reflecting the strategies in this section before considering more restrictive strategies identified in Section 5.2.3.

STRATEGY: REDUCE CITY WATER USE AND LEAD BY EXAMPLE

City operations comprise the single largest customer of Phoenix Water and include both indoor and outdoor water uses. As part of its effort to continue cultural trends in water efficiency and stewardship among its customers, Phoenix must lead by example. Since at least 2002, the City has systematically examined its own water use by department through its Water Efficiency Task Force (WETF). Several of the water conservation program recommendations adopted by the City Council in 2019 for use by Phoenix customers originated in water conservation efforts of City departments. These include the use of smart irrigation controllers by Phoenix Parks and Recreation, plumbing retrofits in City buildings and changes to cooling tower technology at Sky Harbor Airport. By implementing water conservation programs within City operations, Phoenix

Water can evaluate the effectiveness of investments and changes in water use before introducing similar programs to its customers. The WETF was reconvened in 2021, with a renewed effort to examine additional opportunities for water use efficiencies within City operations. In addition, the City Council adopted the following specific water conservation initiatives:

- Development of City landscaping contracts that include water budgets and increased contract management.
- An update of City building codes on a 3-year basis to insure most current efficiency standards.

STRATEGY: WATER BUDGETING AND LEAK IDENTIFICATION

Advances in smart meter, aerial imagery, and calculations of optimal water use send signals to customers about their water use. These tools can be effective for producing either short-term immediate or long-term sustained reductions in use by self-identifying customers that are using excessive quantities of water given the size of the lot, the type of landscaping present, or the size of the structure. When combined with on-site evaluations and customer assistance, these can be extremely helpful in identifying problems and opportunities to make voluntary (or mandatory if necessary) changes in water use behavior. Phoenix has adopted the following measures that are indicative of this strategy:

- Voluntary business water efficiency audits.
- Expansion of HOA Water Efficiency Audit Program.
- Development of web-based residential water budget calculator.

STRATEGY: PILOT AND DEPLOY INCENTIVE PROGRAMS

FIGURE 57. COOLING TOWER AT PHOENIX SKY HARBOR INTERNATIONAL AIRPORT

These programs are designed to reach a maximum number of customers in a minimum amount of time. Rebates, incentives, or subsidized pricing on efficiency devices can be used to significantly alter demand in the short-term. The recommendations adopted by the City Council include these measures:

- Smart irrigation controller subsidy partnership with SRP.
- Expanded toilet retrofit program.
- Commercial cooling tower retrofits.
- Free standardized xeriscape plans for residential properties.

STRATEGY: INCREASED EDUCATION AND OUTREACH TO CUSTOMERS

Phoenix already promotes conservation through many media and outreach channels, and additional focused efforts can assist in the overall goal of creating additional long-term cultural changes related to efficient water use. Some examples in the recent recommendations include:

- Use of door hangers to educate and inform customers about observed leaks and excessive water use.
- Revise State educational standards for water conservation.
- Expand youth educational outreach by collaborating with local educators.
- Establish a volunteer program to assist in water conservation efforts.
- Include an education center at proposed Tres Rios Wetland Visitors' Center.

FIGURE 58. CITY OF PHOENIX YOUTH WATER CONSERVATION EDUCATION AND OUTREACH

5.2.3 Strategies for Achieving Additional Supplies through Curtailment Measures

The long-term sustainability of Phoenix relies on its ability to proactively manage its water portfolio to provide an ample water supply while instilling a conservation ethic that manages demand and achieves efficiencies through periods of cyclical supply challenges. Phoenix Water's demand management strategies are expected to focus on voluntary strategies identified in Section 5.2.2, but it is possible that a severe short-term crisis could require curtailment measures to reduce water consumption. Efforts to accelerate reductions that would otherwise probably occur and remain in place indefinitely (as described in Section 5.2.2) differ from efforts to temporarily reduce water demand (i.e., between a few days and two or three years) and then allow it to return to prior levels. The use of these strategies is not anticipated during the planning period but is identified as a contingency in the event of an unanticipated shortfall in supply.

The 2015 Drought Management Plan and Water Use Reduction Guidelines (DMP) point out that Phoenix has two general strategies – improved water efficiency implemented gradually over time (as described above) and demand curtailment. According to the DMP: “The second strategy, demand curtailment, is characterized as an urgent reduction of water demand necessary to mitigate supply shortfalls. Curtailment programs can be structured to minimize customer impacts and avoid measures that impose severe impacts on a customer’s quality of life and/or the local economy. Curtailment programs typically supplement, rather than replace, efforts to accelerate efficiency improvements.”

The DMP lays out Phoenix’s approach to demand curtailment, which would use a triage approach that establishes a hierarchy of interventions and uses the most innocuous ones first before moving to more burdensome ones. For example, interventions that target leaks (on both sides of the customer meter), wasteful water use (overwatering or watering in the middle of the day in summer), and discretionary uses (water features) would be implemented first. Once reductions from those types of changes are exhausted, interventions that restrict non-essential uses, such as landscape irrigation, would be used. Only in the most pressing situations would curtailment measures significantly impact essential domestic residential or institutional uses. The most challenging parts of implementing the programs are usually dealing with adverse public perceptions about enforcement (“the water police”) and adding staff capable of implementing restrictions on such a huge scale.

It is unlikely Phoenix Water will require the use of curtailment measures in the immediate planning horizon, based on projections of supply and demand as well as implementation of other deficit mitigation strategies. However, in the event further demand reductions are required to meet a specific supply shortfall, the following describes the curtailment strategies that could be pursued.

STRATEGY: IMPOSE LIMITED RESTRICTIONS ON SPECIFIC CUSTOMERS FOR SPECIFIC APPLICATIONS

- Restrictions on irrigation schedules and behavior. A large but important minority of residential, commercial, and industrial customers still irrigate in the middle of the day when evapotranspiration rates are highest. In addition, some overwater landscaping until water spills onto sidewalks and streets or into neighboring properties.
- Irrigation budgeting. New technologies make it possible to monitor individual parcels to identify customers that are using far more water than is normally necessary to maintain a home or business of a given size and type of landscape, and to enforce water budgets. Responses to higher than budgeted water use (within a given percentage) include warnings and possibly fines, or simply tiered water rates that penalize customers as they progressively use more than necessary. This strategy imposes a minor burden on some

residences and businesses, but it is less restrictive than blanket rationing or prohibition of entire uses.

- Higher water rates (temporary surcharges). Higher water rates, potentially in the form of emergency tiers that penalize very high-water users and protect low-income residential customers could be employed during a supply shortfall. Given the current affordable cost of water in Phoenix, these types of increases would be mostly symbolic for most customers unless dramatic increases were implemented, but when used with advertising and outreach campaigns these measures could be important in sending the signal that water is a scarce commodity.
- Mandatory or semi-mandatory audits of high-water users. This initiative could involve either customers that use exceptionally large quantities of water or customers that use uncharacteristic quantities of water. Audits of large water users such as voluntary HOA audits are cost-effective, because the large amounts of water being used indicates that even minor percentage improvements in usage could yield major benefits. Audits could either be required or tied to reductions of higher emergency water rates applied during the shortage and could be combined with subsidies for device and process replacements.
- Mandatory or semi-mandatory replacement of high-use fixtures, appliances, irrigation systems, or industrial processes. In the 1980s, Phoenix successfully promoted a program to remove inefficient toilets to reduce water use. This type of program could be used with auditing or other evaluations of water use and include the subsidization of replacement or upgrade costs. Examples of targeted interventions would be the removal and replacement of inefficient toilets that still exist in hotels, motels, time shares, dormitories, assisted-care facilities, schools, colleges, and hospitals, or the identification and replacement of faulty sprinkler heads on properties with more than five hundred square feet of turf or intensive vegetation.

STRATEGY: IMPOSE RESTRICTIONS ON BROAD CATEGORIES OF USERS FOR MULTIPLE APPLICATIONS

- Bans on certain types of use. Phoenix Water could restrict water use for non-essential purposes such as irrigation, pool-filling, or car-washing in the case of extreme emergencies. Targets would include uses that normally provide lifestyle benefits but whose loss would not jeopardize the health or safety of residents.
- Mandatory rationing. Phoenix Water could require rationing in the form of percent reductions by individual customers, fixed allotments by type of unit or use, or other means in the most extreme emergencies. This type of mandate would be avoided except in the most unusual and extreme circumstances, because of difficulties with equitably and efficiently imposing restrictions through simplistic formulas and even greater difficulties in monitoring compliance.

Curtailment measures, such as those identified in this section, are designed to be used in extraordinary situations and generally, on a temporary basis. Curtailment is not the automatic response to drought conditions because in the desert Southwest, drought is an ongoing cycle.

This remains the case even if drought is further exacerbated by the impacts of climate change. Phoenix intends to pursue as many voluntary demand management techniques as possible in advance of conditions that require curtailment, while maintaining a strategy of curtailment in the event of a particularly severe temporary shortfall that cannot be addressed through voluntary demand management or supply augmentation.

5.3 Supply Augmentation

Water supply shortages are always a potential risk in large cities in the desert Southwest. However, Phoenix has robust supplies under most conditions relative to current and future demand, so Phoenix can explore multiple options to improve supply availability in advance of shortages that pose shortfalls to its customers. In Chapter 4, projections of Phoenix's supplies under prolonged, dry conditions subject to climate change reveal a greater sensitivity to supply shortages for off-project areas versus on-project lands due to the relative differences between the two areas regarding the physical and legal supplies available under various conditions. Phoenix will consider the differences as it considers the need and scope of supply augmentation that might be required in the future.

The most reliable water supplies are renewable and robust enough to withstand significant variations in rainfall and snowmelt. However, as referenced in Chapter 2, climate change has altered historical assumptions about rainfall and snowmelt, adding an additional challenge to renewable supplies. There may be opportunities for additional storage on the Salt and Verde rivers. It may also be possible to lease or acquire high priority on-river Colorado River water. Phoenix can also utilize recycled water for potable uses. Finally, Phoenix can augment reduced supplies by recovering surface water supplies it previously stored underground. Stored supplies, however, are not renewable, but finite in nature. As a final alternative, Phoenix's groundwater allocation is available, although its use is highly regulated. Recent planning for a greater need for pumped supplies (whether for recovery of water previously stored underground or use of Phoenix's groundwater allowance) requires construction of additional infrastructure. Some of the supply augmentation strategies identified below are already in the process of implementation.

5.3.1 Additional Storage on Salt and Verde Rivers

For over 100 years, Phoenix has relied upon water from the Salt and Verde Rivers as the foundation of its water supply portfolio. Supplies from these watersheds are reliable and may not be as susceptible to the impacts of climate change as comparable supplies from the Colorado River. In addition to water supplies delivered by SRP and dedicated to on-project portions of the Phoenix service area, Phoenix has access to Salt and Verde supplies from NCS and Gatewater that can be used anywhere in the Phoenix service area.

The United States Bureau of Reclamation (BOR), SRP, and others, including Phoenix, are currently evaluating the possibility of creating additional storage opportunities on the Salt and

Verde Rivers. These potential additional supplies could prove very valuable to Phoenix during shortages on the Colorado River system.

USE OF ROOSEVELT DAM FLOOD CONTROL SPACE

One opportunity could be the use of flood control space at Modified Roosevelt Dam. When Roosevelt Dam was enlarged in the 1990s adding New Conservation Space, the cities involved in that project also constructed a generous capacity (approximately 556 KAF) for flood control uses. According to the current operating criteria for Roosevelt Dam, water can only occupy the flood control space for 20 days before SRP is obligated to spill, or otherwise release the water downstream. SRP and BOR, in consultation with the U.S. Army Corps of Engineers (COE) and the Maricopa County Flood Control District (MCFCD), are considering options for extending the time water can be held in the flood control space from 20 days to 120 days. There are several legal and technical issues that must be resolved, which means the project will likely proceed through a pilot study before final changes to the flood control manual can be approved. This water could be put to beneficial use within the 120 days of accumulation, so it is unlikely a supply stored in the flood control space in Roosevelt Dam could produce a dependable renewable supply. However, in a study conducted by SRP and BOR, the impacts from climate change were analyzed and indicated the potential for more sudden and variable precipitation events on the Salt and Verde rivers.[37] This study suggests that use of the flood control space could prove to be a valuable investment.

Ideally, water that accumulates in the Roosevelt Dam flood control space could be released for underground storage for future use, but at this time it is not clear whether that will be permitted under the current regulatory framework. The permitted uses of this resource, as well as the other legal and technical issues associated with storing water in the flood control space for longer periods of time must be evaluated in a pilot study. Such a pilot study could demonstrate the efficacy of use of the flood control space as supply augmentation for Phoenix. Plans are underway to introduce a pilot study, and Phoenix anticipates participating with the prospect of acquiring additional water supplies.

HORSESHOE RESERVOIR/MODIFIED BARTLETT DAM

In addition to the flood control space in Roosevelt Dam on the Salt River, BOR and SRP recently completed an appraisal study to address the problem of loss of storage capacity in Horseshoe Reservoir on the Verde River due to sedimentation. Phoenix has its own interest in water stored at Horseshoe Reservoir based on its storage rights in the Horseshoe gates installed by Phoenix in the 1950s. Phoenix's Gatewater storage volumes at Horseshoe Reservoir have been in decline for some time due to natural sedimentation in the Verde River.

[37] *Salt and Verde River Reservoir System SECURE Reservoir Operations Pilot Study* US Bureau of Reclamation, Study Report, January 2020 (https://www.usbr.gov/watersmart/pilots/docs/reports/Final_Reservoir_Operations_Pilot_Report-Salt_and_Verde_Az.pdf).

FIGURE 59. BARTLETT DAM DOWNSTREAM OF HORSESHOE RESERVOIR

The Verde River Sedimentation Mitigation Study seeks to evaluate alternatives to the loss of storage, including options that could create additional storage on the Verde River.

"Modifications" to the current Bartlett Dam downstream of Horseshoe Reservoir could replace lost storage in Horseshoe Reservoir as well as create additional storage, some of which might be available to Phoenix.[38] It is not known at this time how much additional storage capacity, if any, could be created, but even the restoration of the storage capacity from Horseshoe Reservoir would be beneficial to Phoenix supplies. The next step after the appraisal process is a feasibility study, with the selected mitigation solution to follow. Phoenix Water anticipates this project, including any proposed additional structures, will be completed between 2030 and 2040.

5.3.2 Mainstem Colorado River Water

The Colorado River faces significant challenges with the advent of climate change. These challenges, in turn, pose uncertainty to the resiliency and sustainability of Phoenix's allocation from the Colorado River, in addition to the Indian leases with Arizona tribal communities. This is because Central Arizona Colorado River supplies have a relatively low priority (Priority 4) compared to other Colorado River users, both on-river in Arizona as well as within other parts of the Colorado River Basin. Phoenix may consider opportunities to lease or even transfer higher priority Colorado River allocations (Priority 3 or better) from users on-river to augment existing supplies.

As of the date of this Plan, at least one proposal for transfer of an allocation from a private landowner with a Priority 3 right on the Colorado River to a municipality in Central Arizona is pending approval from the Secretary of the Interior. A transfer of this kind must be carefully considered considering on-river Arizona users who anticipate further economic and demand growth from currently unused or underutilized Colorado River allocations. However, it is entirely

[38] The proposed Bartlett Dam modifications are actually new structures slightly downstream of the current Bartlett Dam as opposed to structural modifications to the existing arch dam structure.

possible that additional users will propose to transfer their allocations to entities in Central Arizona.

In addition to potential allocation transfers, federal legislation to allow one or more tribal communities on the Colorado River to lease their Priority 1 water is anticipated in the next several years. Tribal communities such as the Colorado River Indian Tribes (CRIT) have access to the highest priority water on the Colorado River. Based on that priority, it is unlikely that even the most extreme forecasts of climate change could impact access to their share of Colorado River water. Phoenix could lease available water to augment lower priority Colorado River supplies if tribal water becomes available for lease. While it has been suggested that up to 150,000 AF could be available from the CRIT alone, it is not clear what lease terms would be available to Phoenix or what the cost would be for this supply. However, the opportunity to secure these supplies could mean the difference between pursuing more speculative augmentation alternatives (i.e., desalination) and might protect finite groundwater supplies, at least in the foreseeable term.

5.3.3 Acquisition of Colorado River Allocation from Arizona State Land Department

The Arizona State Land Department (ASLD) has a municipal and industrial subcontract with the federal government and CAWCD for approximately 32,000 AF of Colorado River water. ASLD is not a water provider, but at the time the subcontract was awarded in the 1980s, it was anticipated that several municipal providers in Central Arizona would annex certain state lands that would need a renewable water supply. This was noted in ASLD's subcontract in an appendix, which specified that Phoenix would likely need 12,000 AF for state lands north of Jomax Road.

In 2020, Phoenix signed an inter-governmental agreement (IGA) with ASLD in which ASLD agreed to recommend transfer of 12,000 AF of its allocation to Phoenix over a period of approximately 4 years.[39] The transfer is associated with the development of the Biscuit Flat area near the intersection of Interstate 17 and State Route 303 in northwest Phoenix. The IGA contemplates that ASLD will recommend annual transfers of approximately 3,900 AF with the approval of the State Selection Board, BOR, CAWCD and the Arizona Superior Court until the entire 12,000 AF allocation is transferred into Phoenix's municipal and industrial subcontract. This water is the same priority as Phoenix's current subcontract supplies (M&I priority), so while it is a higher priority in the CAP system, it is still subject to shortages based on Colorado River conditions. However, it will provide a valuable supply for the anticipated industrial development in the Biscuit Flat area, as well as an additional supply to buffer against shortage.

5.3.4 Strategies to Recover and Convey Stored Water

The most likely source for episodic augmentation of current Phoenix supplies is from surface water previously stored underground. As described in Chapter 2, Arizona law authorizes ADWR

[39] Intergovernmental Agreement Between the Arizona State Land Department and the City of Phoenix to Facilitate the Development of State Trust Lands Within the City of Phoenix, October 6, 2020.

to permit facilities for the underground storage of renewable water resources (surface and reclaimed waters), which can be stored and then recovered later for the storer's use. Underground storage facilities (USFs) include constructed basins, constructed wells or managed basins. Groundwater savings facilities (GSFs) are used for storage where a previously existing groundwater use (such as agricultural land) is replaced by a renewable supply.[40]

In 1996, the State of Arizona created the Arizona Water Banking Authority (AWBA). The AWBA has several missions, but key among them is storing the state's available unused or excess Colorado River water underground to hedge against potential future shortages for municipal and industrial (M&I) users in the Phoenix AMA.[41] In more recent years with the lack of excess Colorado River water, AWBA has been purchasing existing LTSCs for the same purpose. Through 2019, more than 1.5 million LTSCs have been accrued in the Phoenix AMA to firm the supplies of M&I subcontractors such as Phoenix during shortage.

Representatives of ADWR, CAWCD, and the AWBA, in cooperation with stakeholders, recently updated a recovery plan that identifies the duties and responsibilities of the parties as they relate to recovery of the AWBA's LTSCs. However, CAWCD and the AWBA have little recovery infrastructure to recover LTSCs stored in aquifers outside of the Phoenix metropolitan area. It appears that many M&I subcontractors, including Phoenix, will need to use their own infrastructure, or make agreements with other parties to use their well infrastructure for recovery of credits distributed by the AWBA.

In addition to the LTSCs Phoenix will receive from the AWBA to firm Phoenix's Colorado River subcontract, Phoenix has been earning LTSCs through the storage of its own Colorado River entitlements, NCS water, and reclaimed water.[42] When recovered, the water may be used directly by Phoenix within its service area, or it may be exchanged elsewhere for another supply. Storage of renewable water supplies, and subsequent recovery of the water when needed to ameliorate drought, shortage or emergency conditions, is an important deficit mitigation strategy for Phoenix.

Several years ago, Phoenix began storing the entirety of its Colorado River water supplies not dedicated to customer demands to accumulate LTSCs for future use. To accomplish this, Phoenix installed aquifer storage and recovery (ASR) wells, maximized deliveries to constructed USFs such as GRUSP and the Avondale Wetlands in the Phoenix area and SAVSARP and AVRP in the Tucson area, and pursued additional agreements to recover and/or exchange supplies. Phoenix also has permits to deliver Colorado River water to GSFs owned by the New

[40] A GSF is a facility in an active management area at which groundwater withdrawals are eliminated or reduced by recipients who use in lieu water on a gallon-for-gallon substitute basis for groundwater that otherwise would have been pumped from within that active management area.
[41] CAWCD defines excess water as all Central Arizona Project Water that is in excess of the amounts used, resold, or exchanged pursuant to long-term contracts and subcontracts for Project Water service.
[42] SRP Normal Flow, Salt River Project Stored and Developed Water, and RID Exchange water received from SRP cannot be recharged to earn long term storage credits.

Magma Irrigation District and Queen Creek Irrigation District. Phoenix has been delivering reclaimed water to the RID GSF for many years and is in the process of expanding storage at this location to include Colorado River water and NCS supplies. These opportunities increase the resiliency of Phoenix's portfolio of supplies and prepares for the possibility of more severe shortage conditions in the future.

Phoenix is developing strategic recovery mechanisms for both LTSCs it has stored as well as LTSCs that may be distributed by the AWBA during certain levels of shortage. Certain recovery arrangements provide greater benefits and flexibility than others. Whenever possible, Phoenix will try to use recovery mechanisms that provide the closest nexus between the location where water was stored and where it is recovered.

Pursuant to state law, an LTSC holder can recover (pump) the LTSC anywhere in the same Active Management Area where it was stored so long as the recovery permit conditions are not prohibitive, regardless of whether there is a hydrologic connection with the storage location. Although this conceptually provides flexibility, during shortage conditions many municipalities in the Phoenix metro area will likely simultaneously pump LTSCs from local aquifers with no hydrologic connection to the facilities where the water was originally stored. This may result in declines in aquifer levels, that in some instances can affect the ability to recover stored LTSCs in a specific location. At its most extreme, this type of recovery may pose a risk to the physical availability of groundwater in local production wells. In an effort to avoid this risk, Phoenix plans to prioritize recovery of stored water by using infrastructure that is hydrologically connected to the aquifer where the water was stored or is otherwise within the Area of Impact (AOI) designated by ADWR. Phoenix will also consider this strategy as it continues to pursue opportunities to maximize storage and later recovery of available surface water.

It is important that Phoenix continually optimize the combination of water management mechanisms to meet current and future needs while considering the long-term impacts to sustainability and resiliency of available resources. Important factors that are considered in the current strategy for storage and recovery are:

- the hydrologic benefits of local storage to Phoenix aquifers;
- the greater likelihood of off-project shortages and the need to provide water to these areas in times of shortage;
- the availability and cost of infrastructure to recover and convey water to where it is needed;
- the agreements that will need to be executed and the regulations that will need to be adhered to in order to effectuate the strategy; and
- the likelihood that water recovered from certain aquifers will require advanced water quality treatment due to contamination.

It would be optimal to store and recover water within the Phoenix Water service area, but there is limited local storage capacity available, limited access to available off-project land to create additional storage capacity, and some aquifers within the Phoenix Water service area are contaminated or otherwise unsuitable for underground storage. In addition, the volume of water available to Phoenix for storage exceeds the available capacity for storage in the Phoenix AMA in non-shortage years. Moreover, Phoenix must contract with partners to store and/or recover enough volumes of water necessary to mitigate shortage risks. The following strategies for storage and recovery reflect the experience of Phoenix Water over the past six years and demonstrate the need for creativity and flexibility in working with partners. This list is not exhaustive, and over time will likely expand to reflect additional arrangements with partners to meet Phoenix Water's need for storage and recovery capacity.

STRATEGY: CREATE ADDITIONAL STORAGE CAPACITY IN THE PHOENIX WATER SERVICE AREA

Figure 60. "A Time Machine Called Tinaja" by Bobby Zokaites, City of Phoenix public art and greenspace at a former City well site.

The ideal approach is to store water in a City-owned facility within the service area to provide direct control over recharge operations and the capability for localized recovery. Storage should be prioritized for areas where there is a need to replenish local aquifers where historical pumping has caused groundwater level declines. Excessive declines can cause land subsidence from aquifer compaction and the development of earth fissures along with a degradation of water quality as water levels deepen. As noted earlier, Phoenix continues to construct aquifer storage and recovery (ASR) wells in off-project areas of North Phoenix to advance this strategy.

Another potential method which could be considered in the future is recharging water in a managed underground storage facility (USF) located within an existing streambed or the Salt River. In this latter option, state law only awards LTSCs for 50% of the water recharged in a managed USF, but it may be the only option for recharging more significant volumes of water within the Phoenix Water service area. The advantage of using either of these methods is that it utilizes City-owned facilities so there is a high degree of certainty that the LTSCs earned can be easily recovered by Phoenix in the future. However, as previously noted, it is unclear whether there are suitable locations for an USF within the Phoenix service area, and in any event, there are certainly insufficient existing or possible locations within the service area to store all the available water Phoenix cannot utilize during non-shortage years.

STRATEGY: DEVELOP PARTNERSHIPS TO STORE AND RECOVER LTSCS WITH LOCAL PARTNERS

This option involves partnerships to store water within the Phoenix metropolitan area and recover it using wells owned by third parties. In 2018, Phoenix and SRP entered into an agreement that allows Phoenix to lease capacity in SRP's well network to recover LTSCs stored within the SRP District, including those stored in SRP's GSF and GRUSP.[43] Under the agreement, Phoenix can recover up to 20,000 AF per year during the 40-year duration of the agreement. Phoenix will use its existing Water Transportation Agreement with SRP to deliver the recovered water to Phoenix treatment facilities via SRP's canals. The agreement also provides that Phoenix can recover additional LTSCs it acquires from other parties who stored water in SRP's GSF or at GRUSP. Phoenix also has an agreement with SRP that allows recovery of LTSCs stored at the RID GSF within the SRP District. These agreements are critical to Phoenix's recovery in the SRP District and, together with NCS and Gatewater supplies, will likely constitute most of the water used in Phoenix's Drought Pipeline project. It reduces the burden on new well capacity in the northern portion of the City to recover LTSCs.

In an associated agreement with SRP, Phoenix has the right of first refusal to utilize 15% of the annual storage capacity in the SRP GSF and 15% of SRP's share of storage capacity in GRUSP through 2028.[44] The combination of the two agreements provides Phoenix a reliable storage and recovery partner in SRP and its network of wells throughout the SRP District. In recent years, storage capacity at both SRP GSF and GRUSP has been limited, but the existing agreements guarantee Phoenix continued access to the extent it is available.

Another example of this strategy is the agreement between Phoenix and the City of Avondale for storage and recovery of Phoenix Colorado River water supplies in Avondale's USF. Phoenix stores Colorado River water in Avondale's USF. Phoenix and Avondale have agreed to an exchange partnership so when Phoenix is ready to recover the water stored in Avondale's USF, Avondale will use its own wells to recover the credits on behalf of Phoenix. Then Avondale will utilize the recovered credits to meet its own service area needs and exchange with Phoenix by directing delivery of an equivalent volume of its available Colorado River water directly to Phoenix. This partnership benefits both cities as Avondale's aquifer remains robust with Phoenix's water, and Phoenix receives delivery of additional Colorado River supplies directly to its water treatment facilities during shortage.

STRATEGY: DEVELOP PARTNERSHIPS TO RECOVER OTHER CREDITS IN THE PHOENIX AMA

In recent years, Phoenix has stored available Colorado River water in other USFs and GSFs in the Phoenix AMA. Phoenix has earned LTSCs at New Magma Irrigation and Drainage District (New Magma) GSF and the Queen Creek Irrigation and Drainage District (Queen Creek) GSF,

[43] "Well Capacity Lease and Water Recovery Agreement Among City of Phoenix, Salt River Valley Water Users' Association and Salt River Project Agricultural Improvement and Power District," August 1, 2018.
[44] "Agreement for Access to Water Storage Capacity Among the City of Phoenix, Salt River Valley Water Users' Association and Salt River Project Agricultural Improvement and Power District," December 21, 2018.

both located in the southeast portion of the metropolitan area. Those facilities are outside the Phoenix service area or the Area of Impact of Phoenix wells. Pursuant to state law, the credits can be recovered in the Phoenix service area because they are in the same AMA, but such recovery will be remote from the respective storage facility.

In its recent IGA with ASLD, Phoenix agreed to assist ASLD with underground storage of a portion of its remaining Colorado River allocation. Through 2024, Phoenix has agreed to provide available capacity in its own underground storage facility in its ASR wells for ASLD to order and store a portion of its Colorado River allocation. ASLD will then own LTSCs in Phoenix's USF. In return, ASLD has agreed to trade the LTSCs it earns from storage in Phoenix's ASR wells for existing LTSCs Phoenix owns in New Magma and Queen Creek GSFs. While the number of credits earned by ASLD in Phoenix's USF may not equal the credits Phoenix has already accrued at the two GSFs, this trade or exchange provides a way for Phoenix to recover some of the LTSCs stored outside of the Phoenix service area, which is consistent with its strategy of recovering credits within the area of hydrological impact. Phoenix may still need to find exchange partners for the remaining LTSCs it accrued at New Magma and Queen Creek GSFs.

STRATEGY: STORAGE AND RECOVERY OUTSIDE THE PHOENIX AMA

One of the keys to Phoenix's recent successful storage of large volumes of Colorado River water has been its partnerships with Tucson Water and the Metropolitan Domestic Water Improvement District (Metro). Both Tucson Water and Metro have large underground storage facilities in the Avra Valley, an area just west of Tucson with a large geologic basin that is ideal for aquifer storage. Unlike the Phoenix AMA, the Tucson AMA has a vast amount of available storage capacity. Through unique exchange partnerships with Tucson and Metro, Phoenix has found a way to store and recover its water over 150 miles from its service area.

Since 2015, Phoenix has been ordering Colorado River water for storage in Tucson Water's Southern Avra Valley Storage and Recovery Project (SAVSARP) and Metro's Central Avra Valley Storage and Recovery Project (AVRP). As of 2020, Phoenix has stored over 115,000 AF of Colorado River water in Tucson aquifers. Phoenix and its Tucson AMA partners have developed exchange agreements to facilitate recovery of the LTSCs stored in the Tucson AMA. During times in which Phoenix wants to recover water stored in the Tucson AMA, it will use existing wells owned by Tucson Water or Metro to pump the water. Tucson or Metro will then utilize the pumped water in its respective distribution system for its customers and in return, will direct delivery of an equivalent volume of its Colorado River entitlement for direct delivery to a Phoenix water treatment plant. Each exchange is a benefit to both parties. Tucson Water has the largest M&I subcontract in the CAP system, so even during times of shortage, Phoenix can call on Tucson's allocation. Likewise, Tucson already exclusively serves its customers with water pumped from its aquifers, so a Phoenix "call" for delivery of Tucson's Colorado River supplies will not compromise Tucson's customers in any way. Metro operates its water system in a similar fashion. Phoenix will likely continue to store available Colorado River water in

Tucson aquifers, as the only risk to the exchange is in the event there is no available Colorado River water in the CAP system.

A recent concept that might facilitate further storage and recovery outside the Phoenix AMA is an additional interconnection between the CAP and the SRP systems. The CAP/SRP Interconnection Facility (CSIF) currently connects the systems at Granite Reef Dam to allow Colorado River water to enter the SRP canal system. Phoenix currently utilizes the CSIF to move Colorado River water on-project for multiple uses, including wheeling of Avondale and EPCOR's Colorado River supplies through the Phoenix distribution system, increasing flexibility, and enhancing regional water management. A proposed SRP/CAP Interconnection Facility (SCIF) would allow water from the Salt and Verde Rivers to enter the CAP at SRP's South Canal. The SCIF would facilitate movement of Phoenix's NCS supplies for storage outside of the Phoenix AMA, subject to acceptable exchange agreements with partners outside the AMA. As previously noted, this is just one example of the types of new water management strategies and regional collaboration that could be implemented with investments in improved infrastructure such as the SCIF.

5.3.5 Use of Groundwater Allowance

Groundwater may be pumped and used by Phoenix pursuant to Arizona state statutes, but with strict controls as specified in Arizona's Assured Water Supply (AWS) Rules, which became effective in 1995. These rules are monitored by the Arizona Department of Water Resources (ADWR) and require a demonstration of at least 100 years of renewable water supplies for new development to occur. In 2010, the City of Phoenix obtained a Designation of Assured Water Supply (DAWS) from ADWR under these rules. The designation allows Phoenix to plan future growth for the next 100 years, because it has demonstrated enough renewable supplies to meet these needs. As part of the designation's water supply portfolio, a volume of groundwater in storage has been set aside for Phoenix's use. Phoenix's allowance of existing fossil groundwater resources is the most basic component of its water resource portfolio, and as such, is generally the source of last resort.

The groundwater allowance volume allocated to Phoenix in the 2010 designation is 36,995 AF per year (AF/yr) to meet annual demands, or a total of 3,699,500 AF over 100 years. This groundwater volume was demonstrated to be physically, continuously, and legally available for 100 years and is consistent with the management goal of the Phoenix AMA. This groundwater provides Phoenix flexibility in when and how much of this resource to use for managing its future water supplies. The allowance includes groundwater credits that accrue to Phoenix each year to reflect the incidental recharge to local aquifers occurring from service area water usage. Additional groundwater may be pumped beyond the groundwater allowance, but it would require Phoenix to replenish any groundwater used in excess of that provided in its designation.

The DAWS for Phoenix must be renewed with ADWR at least every 15 years, so the next designation of assured water supply will occur in 2025. Many of the other cities in the Phoenix metropolitan area will also be "redesignated" at the same time, requiring a comprehensive groundwater model of the region to determine each city's respective groundwater allowance. While Phoenix rarely uses its groundwater allowance, it is not clear at this time whether the current groundwater allowance in the 2010 designation will be sustainable under a revised groundwater model or whether the annual volume will change as a result of the 2025 redesignation process.

5.3.6 Desalination

For many years, government officials and some policy makers have considered desalination of sea water or brackish groundwater to be a viable (and potentially ultimate) solution to water resource supply challenges in Arizona. As of the date of this plan, only the topic of desalination has its own committee as part of the Governor's Water Augmentation Innovation and Conservation Council.[45] The term *desalination* has been used to describe both the treatment of certain brackish groundwater, as well as the treatment of sea water. Neither is ideal from a financial or technical perspective, yet neither concept can be ruled out completely as a legitimate source of water.

Brackish groundwater supplies located in parts of the Phoenix AMA and outside the AMA possess moderately high TDS (salinity) levels, in some cases exceeding 2,500 mg/l. This brackish water tends to occur in areas with high water table conditions and is relatively easy to access for well extraction during shortage conditions. The costs associated with treatment of this water are high and include the challenge of disposal of the brine by-product. In addition, despite its poor quality, use of brackish groundwater pumped from within AMAs may be subject to the limits imposed by the Groundwater Code and still has potential impacts to groundwater levels in the Phoenix service area. While brackish groundwater pumped outside of the AMAs is not subject to the same limitations, it is subject to laws regarding importation as well as the additional costs of transportation.

The concept of creating potable water from the vast resources of the sea has always appealed to desert dwellers. In recent years, desalinated sea water has been used in Israel and California for potable uses. Although the technology is readily available, the cost is significant and the distance from sea water sources poses unique challenges. The TDS of seawater is roughly 35,000 ppm and would require considerably more capital to source, transport, and treat than brackish groundwater. However, Phoenix could ultimately partner with other regional water providers to access desalinated sea water to reduce vulnerabilities from shortage. Though the realization of such an effort is likely decades away, the scope and scale of the effort will require significant planning and capital expenditures.

[45] In addition to the Desalination Committee, there is a more general Long Term Water Augmentation Committee which considers all other mitigation strategies to augment supplies.