Water Augmentation Study

LONG-TERM WATER AUGMENTATION OPTIONS FOR ARIZONA

Funded by the Arizona Department of Water Resources and a grant from the Bureau of Reclamation Phoenix Area Office Water Conservation Field Services Program

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### Abbreviations

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<tr>
<td>AACE</td>
<td>Association for the Advancement of Cost Engineering</td>
</tr>
<tr>
<td>ADWR</td>
<td>Arizona Department of Water Resources</td>
</tr>
<tr>
<td>AF</td>
<td>acre-foot</td>
</tr>
<tr>
<td>AFY</td>
<td>acre-feet per year</td>
</tr>
<tr>
<td>AMA</td>
<td>Active Management Area</td>
</tr>
<tr>
<td>APP</td>
<td>Aquifer Protection Program</td>
</tr>
<tr>
<td>BoR</td>
<td>United States Bureau of Reclamation</td>
</tr>
<tr>
<td>CAG</td>
<td>Central Arizona Governments</td>
</tr>
<tr>
<td>CAGRD</td>
<td>Central Arizona Groundwater Replenishment District</td>
</tr>
<tr>
<td>CAWCD</td>
<td>Central Arizona Water Conservation District</td>
</tr>
<tr>
<td>CAP</td>
<td>Central Arizona Project</td>
</tr>
<tr>
<td>CIP</td>
<td>Capital Improvement Program</td>
</tr>
<tr>
<td>CSIF</td>
<td>CAP-SRP Interconnect Facility</td>
</tr>
<tr>
<td>DPR</td>
<td>direct potable reuse</td>
</tr>
<tr>
<td>EPA</td>
<td>Environmental Protection Agency</td>
</tr>
<tr>
<td>GPD</td>
<td>gallons per day</td>
</tr>
<tr>
<td>gpm</td>
<td>gallons per minute</td>
</tr>
<tr>
<td>GWAICCC</td>
<td>Governor’s Water Augmentation, Innovation, and Conservation Council</td>
</tr>
<tr>
<td>IMS</td>
<td>Irrigation Management Services</td>
</tr>
<tr>
<td>INA</td>
<td>irrigation non-expansion area</td>
</tr>
<tr>
<td>IPR</td>
<td>indirect potable reuse</td>
</tr>
<tr>
<td>LTSC</td>
<td>long-term storage credits</td>
</tr>
<tr>
<td>MAG</td>
<td>Maricopa Association of Governments</td>
</tr>
<tr>
<td>mg/L</td>
<td>milligrams per liter</td>
</tr>
<tr>
<td>NACOG</td>
<td>Northern Arizona Council of Governments</td>
</tr>
<tr>
<td>NCS</td>
<td>New Conservation Space</td>
</tr>
<tr>
<td>NEPA</td>
<td>National Environmental Policy Act</td>
</tr>
<tr>
<td>NHPA</td>
<td>National Historic Preservation Act</td>
</tr>
<tr>
<td>NGO</td>
<td>non-governmental organization</td>
</tr>
<tr>
<td>NIA</td>
<td>Non-Indian Agriculture</td>
</tr>
<tr>
<td>PAG</td>
<td>Pima Association of Governments</td>
</tr>
<tr>
<td>RO</td>
<td>reverse osmosis</td>
</tr>
<tr>
<td>ROW</td>
<td>right-of-way</td>
</tr>
<tr>
<td>SCIF</td>
<td>SRP-CAP Interconnect Facility</td>
</tr>
<tr>
<td>SEAGO</td>
<td>SouthEastern Arizona Governments Organization</td>
</tr>
<tr>
<td>SWIFT</td>
<td>State Water Implementation Fund for Texas</td>
</tr>
<tr>
<td>TDS</td>
<td>total dissolved solids</td>
</tr>
<tr>
<td>Acronym</td>
<td>Description</td>
</tr>
<tr>
<td>---------</td>
<td>-------------</td>
</tr>
<tr>
<td>UER</td>
<td>Urban Enhanced Runoff</td>
</tr>
<tr>
<td>UIC</td>
<td>underground injection control</td>
</tr>
<tr>
<td>WIFA</td>
<td>Water Infrastructure Finance Authority</td>
</tr>
<tr>
<td>WWDC</td>
<td>Wyoming Water Development Commission</td>
</tr>
<tr>
<td>WWMPP</td>
<td>Wyoming Weather Modification Pilot Program</td>
</tr>
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</table>
Acknowledgements

The Long-Term Water Augmentation Committee of the Governor's Water Augmentation, Innovation, and Conservation Council

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Jeri McAnerny
Section 1

INTRODUCTION

A part of the Governor’s Water Augmentation, Innovation, and Conservation Council (GWAICC) includes the Long-Term Water Augmentation Committee (Committee), which is tasked with finding methods of augmenting water supplies in Arizona. The Arizona Department of Water Resources (ADWR) managed the Committee meetings, and selected the consulting team of Carollo Engineers, Inc., Montgomery & Associates, and Westland Resources (Project Team) to provide research and evaluation support services to the Committee.

As Arizona continues to grow and use an increasing portion of its water resources, it is important to plan ahead and find additional water supplies as well as more efficient ways to use current water supplies through conservation so that Arizona can continue to grow and prosper.

1.1 Project Objective

The purpose of this water augmentation project is to evaluate a series of water augmentation methods identified by the Committee that could be applied to the twenty-two planning areas throughout the state of Arizona. The outcome of this project is a series of suggestions that water users in each of the planning areas could apply to their unique situation when doing so would extend existing water supplies or provide new water supplies. In addition, one objective of the study was to identify long-term water augmentation options that could become Arizona’s next water supply once currently developed water supplies are fully utilized.

The objectives of this project do not include taking water that has been allocated for agriculture and re-purposing this water to enable municipal growth. The objectives of this project also do not include expanding agriculture with new water supplies. The recommendations in this project are not provided as mandates, but as suggestions to apply when the augmentation option provides desired water supply benefits. Some of the water augmentation methods are not economically viable today but are expected to be viable in the future when the willingness to pay the higher cost of water augmentation aligns with the cost of water augmentation projects. Future advances in technology may also make some water augmentation options more economically viable. The results of this study are recommendations only. It is the responsibility of each local community to develop their water supply plans and assess which water augmentation options would best meet their needs.

1.2 Project Outcomes

One of the key conclusions from this study is that the water augmentation options available to Arizonans to a large extent have already been identified, and some are in the process of being developed. Our task as Arizonans is to work with the water resources that we have to provide the water needed for continued growth, prosperity, and environmental sustainability. Additional water supplies coming from outside of Arizona are not expected other than opportunities that come through Minute 323 (discussed in Section 3).
The following are key outcomes from this project:

- Additional water supplies that have not yet been fully utilized are identified.
- Importing water supplies from other states is being removed from further consideration.
- Best Practices where Arizona currently provides leadership are being re-emphasized for the additional benefits that can come from implementing these practices more fully throughout the state.
- Projects that can improve the efficient utilization of water are identified.
- Water augmentation opportunities requiring additional research and investigation have been identified so that additional effort can be channeled toward these investigations.
- Arizona needs to make progress on resolving water rights issues, and in extending water management practices to portions of the state that would have more sustainable water supplies with effective groundwater management.

1.3 Report Outline

This report is organized as follows:

- Section 2 describes how the project was completed, and includes a description of the planning areas used for this study and water augmentation options evaluated.
- Section 3 describes the water augmentation options available for Arizona.
- Section 4 lists the Best Practices that can be used to extend existing water supplies.
- Section 5 identifies projects that could be undertaken between willing parties that would improve water management.
- Section 6 describes water augmentation ideas that may have potential but additional research is needed before these ideas can reliably augment water supplies.
- Section 7 presents impediments to water augmentation that need to be addressed to fully use Arizona's water resources.

Section 2

WATER AUGMENTATION EVALUATION PROCESS

2.1 Arizona Water Planning Areas

This study is based on the twenty two planning areas as delineated in the 2014 ADWR "Arizona's Next Century: A Strategic Vision for Water Supply Sustainability". Figure 1 presents a map of the planning areas that were used in this study. Table 1 presents each planning area with population and historical water use information to help characterize each planning area.
Figure 1  Arizona Strategic Water Planning Areas

Legend

- Water Resource Planning Areas

Data Sources:
- Planning Areas, AMAs: ADWR
- Rivers, River Basin, Street Map, State Boundaries: ESRI
Table 1  Water Planning Area Community Population and Historic Water Use

<table>
<thead>
<tr>
<th>Planning Area</th>
<th>Population in Major Communities(^{(1,2,3)})</th>
<th>2010 Municipal Water Use(^{(1)}) (AF)</th>
<th>2010 Agricultural Water Use(^{(1)}) (AF)</th>
<th>2010 Industrial Water Use (Mining, Power plants, Rock production, Other industrial, Turf)(^{(1)}) (AF)</th>
<th>2010 Total Water Use(^{(2)}) (AF)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Apache</td>
<td>12,545</td>
<td>4,378</td>
<td>23,860</td>
<td>3,323</td>
<td>31,561</td>
</tr>
<tr>
<td>Arizona Strip</td>
<td>9,669</td>
<td>3,315</td>
<td>2,100</td>
<td>882</td>
<td>6,324</td>
</tr>
<tr>
<td>Basin &amp; Range AMAs</td>
<td>2,036,069</td>
<td>1,381,251</td>
<td>2,029,432</td>
<td>215,626</td>
<td>3,647,990</td>
</tr>
<tr>
<td>Bill Williams</td>
<td>5,504</td>
<td>1,555</td>
<td>2,700</td>
<td>14,957</td>
<td>19,212</td>
</tr>
<tr>
<td>Central Plateau</td>
<td>72,292</td>
<td>12,248</td>
<td>1,962</td>
<td>3,952</td>
<td>18,702</td>
</tr>
<tr>
<td>Cochise</td>
<td>21,749</td>
<td>8,869</td>
<td>256,400</td>
<td>6,221</td>
<td>272,224</td>
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<tr>
<td>Colorado River Main Stem - North</td>
<td>92,067</td>
<td>37,990</td>
<td>81,500</td>
<td>5,019</td>
<td>124,509</td>
</tr>
<tr>
<td>Colorado River Main Stem - South</td>
<td>126,799</td>
<td>49,480</td>
<td>900,500</td>
<td>2,515</td>
<td>952,495</td>
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<td>East Plateau</td>
<td>32,997</td>
<td>13,478</td>
<td>35,325</td>
<td>45,597</td>
<td>94,420</td>
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<td>Gila Bend</td>
<td>1,922</td>
<td>867</td>
<td>351,500</td>
<td>5,400</td>
<td>357,940</td>
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<tr>
<td>Hassayampa/Agua Fria</td>
<td>12,672</td>
<td>4,595</td>
<td>1,800</td>
<td>2</td>
<td>7,183</td>
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<tr>
<td>Lower Gila</td>
<td>7,371</td>
<td>2,028</td>
<td>393,000</td>
<td>0</td>
<td>398,695</td>
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<tr>
<td>Lower San Pedro</td>
<td>11,925</td>
<td>3,234</td>
<td>4,700</td>
<td>16,424</td>
<td>24,358</td>
</tr>
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<td>Navajo/Hopi Tribal</td>
<td>31,780</td>
<td>19,022</td>
<td>1,963</td>
<td>25,419</td>
<td>46,404</td>
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<tr>
<td>Northwest Basins</td>
<td>28,068</td>
<td>12,782</td>
<td>0</td>
<td>1,399</td>
<td>16,257</td>
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<tr>
<td>Roosevelt</td>
<td>30,570</td>
<td>7,105</td>
<td>2,685</td>
<td>16,399</td>
<td>26,189</td>
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<td>Upper Gila</td>
<td>19,231</td>
<td>7,875</td>
<td>127,340</td>
<td>8,081</td>
<td>143,389</td>
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<td>Upper San Pedro</td>
<td>58,758</td>
<td>19,168</td>
<td>8,800</td>
<td>1,915</td>
<td>29,925</td>
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<td>Verde</td>
<td>125,748</td>
<td>33,886</td>
<td>25,362</td>
<td>5,003</td>
<td>64,251</td>
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<td>West Basins</td>
<td>3,601</td>
<td>1,016</td>
<td>250,000</td>
<td>1,107</td>
<td>252,123</td>
</tr>
<tr>
<td>West Borderlands (Primarily tribal lands)</td>
<td>2,816</td>
<td>1,024</td>
<td>500</td>
<td>0</td>
<td>1,524</td>
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<tr>
<td>Western Plateau (Primarily tribal lands)</td>
<td>1,434</td>
<td>551</td>
<td>0</td>
<td>1</td>
<td>552</td>
</tr>
</tbody>
</table>

Notes:
(2) Total population from major cities, population centers or communities within the planning area
Abbreviation:
AF = acre-feet
2.2 Water Augmentation Methods

The Committee selected a set of water augmentation options that were to be evaluated in this project. Then during the project, three additional water augmentation options were added to the list. Table 2 presents the water augmentation methods that were initially considered in this project. Not all of these augmentation methods were used in the final augmentation options that were developed. Many of the augmentation options use multiple augmentation methods from Table 2.

Table 2 Water Augmentation Methods

<table>
<thead>
<tr>
<th>Short Term Augmentation (Can be Implemented any Time)</th>
<th>In-State Exchanges/Transfers</th>
<th>Long-Term Augmentation (May Take 30 years to Implement)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Conservation - Municipal</td>
<td>Groundwater</td>
<td>Ocean Desalination</td>
</tr>
<tr>
<td>Conservation - Ag</td>
<td>Groundwater/Surface water</td>
<td>Deep Aquifer Wells</td>
</tr>
<tr>
<td>Aquifer Recharge - Urban Runoff</td>
<td>Surface Water</td>
<td>Voluntary Out of State Importations</td>
</tr>
<tr>
<td>Aquifer Recharge-Treated Recycled Water</td>
<td>Reclaimed Water</td>
<td>Voluntary Out of State Exchanges</td>
</tr>
<tr>
<td>Potable Reuse - Treated Recycled Water</td>
<td></td>
<td>Weather Modification</td>
</tr>
<tr>
<td>Non-Potable Reuse - Treated Recycled Water</td>
<td></td>
<td>Forest Restoration</td>
</tr>
<tr>
<td>Modify Operation of the Roosevelt Dam(1)</td>
<td></td>
<td>Phreatophyte Management(1)</td>
</tr>
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<td>SRP-CAP Interconnect Facility(1)</td>
<td></td>
<td>Brackish Desalination</td>
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<td>Water Banking</td>
<td></td>
<td></td>
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<tr>
<td>Regulatory Revisions</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Note: (1) Added during the Project.

2.3 Water Augmentation Evaluation Process

The total number of water augmentation options is 22(3) possibilities multiplied by 22 planning areas gives 550 water augmentation possibilities. A definition of each augmentation method was prepared so that the Committee and the Project Team had a common understanding of each augmentation method. The Committee provided an initial set of evaluation categories that were used to begin narrowing down the water augmentation possibilities applicable to each planning area, and to provide a means of evaluating and comparing water augmentation methods. Using this criteria, the team initially conducted a high level evaluation of water augmentation possibilities for each of the planning areas. The objective of this high level evaluation was to quickly identify augmentation ideas that were not practical or possible for a particular planning area, to quickly reduce the number of water augmentation possibilities that needed to be considered.

"Fact Sheets" were prepared for each water augmentation method with the information that was relevant for the evaluation criteria, so that augmentation methods could be compared.
against each other. The fact sheets formed the basis of the project descriptions in this report and included information such as:

- Applicability
- Implementation timeframe
- Benefitting planning areas
- Adaptability
- Water Yield
- Cost/AF
- Economic viability
- Project Components
- Partners
- Permitting requirements
- Regulatory, political, technical challenges

The fact sheets provided the Committee with the opportunity to review and explore in further detail the benefits of each augmentation method.

Based on discussions with the Committee and evaluations by the Project Team, the water augmentation methods were categorized based on the type of benefit that was provided.

For example, water conservation and the various types of reclaimed water development were categorized as "Best Practices" and not water augmentation. Arizona has been a leader in municipal water conservation and water reuse. There are additional opportunities to do more water conservation and extend the benefits of reclaimed water to additional areas of the state. However, neither of these methods produce a new water supply. Likewise, agricultural conservation should be increased where economically viable, but water made available through conservation can only benefit the farms that have the allocation and therefore is considered to be a best practice and not a new water source. One or more Best Practices can be implemented in each of the planning areas and can be used to obtain additional value from existing water supplies.

Another group of water augmentation options was categorized as "Projects that benefit willing parties." These projects generally provide flexibility and an additional means of using or transferring water that provides benefits to one or more parties. These projects enable more effective use of existing water resources. Examples include constructing a Salt River Project (SRP) to Central Arizona Project (CAP) connection at the Granite Reef Dam, and using the emergency storage space behind the Roosevelt Dam to provide storage benefits to SRP customers.

A third group of water augmentation options may have potential to generate new water or are important to maintain existing water supplies, but additional research and investigation is needed to quantify the benefits and overcome implementation challenges. These water augmentation options include weather modification, phreatophyte management, and forest management. Although it is difficult to quantify the water volumes and beneficiaries of these potential water augmentation practices, these practices are important. Forestry management in particular is important to not only increase water supplies, but to protect water supplies from the damaging effects of forest fires and maintain water quality.

During the evaluation, barriers to water augmentation were also identified. These barriers in most cases prevent utilization of existing water supplies, and therefore require attention to resolve. These barriers include the ongoing Gila River and Little Colorado River adjudications, Indian water right claim settlements, and lack of rural area groundwater management and planning. Cost is also a significant barrier to water augmentation. In some areas of the state, the
volume of groundwater available for use is not known because studies have not been completed to evaluate groundwater use. The need for additional water supplies has also not yet been quantified. Understanding available groundwater supplies, understanding water ownership, and knowing projected water demands are pre-requisites to any water augmentation.

Some water augmentation methods on the list in Table 2 are embedded in another form of water augmentation or Best Practice. These include water banking, regulatory revisions, water exchanges, and water transfers. These items are addressed where appropriate as a component of other water augmentation options.

Augmentation options that included importing water from other states were considered, but were eliminated from consideration because of legal constraints, actual water availability, and extremely high costs.

The water augmentation options that remain after this evaluation were ocean desalination, brackish groundwater desalination, and transporting groundwater stored in the West Basin Planning Area, i.e., Harquahala Valley and Butler Valley as allowed under current statute. McMullen Valley could be a possibility if land ownership requirements needed to allow transporting groundwater are met.

Permitting and regulatory requirements for water augmentation options were evaluated and identified. Actual permitting and environmental requirements will need to be established once actual sites for water augmentation infrastructure are determined. Appendix A lists the permits and regulatory requirements that may need to be satisfied for different types of water augmentation projects.

Funding options for water augmentation opportunities were also evaluated. In most cases, municipal utilities would be implementing the water augmentation projects and would use the same funding options that are normally used to fund water infrastructure such as bonding, rates, impact fees, and Water Infrastructure Finance Authority (WIFA) loans. In some cases water utilities may partner with other entities to obtain funding.

2.3.1 Planning Level Costing Methodology

Present worth planning level project cost estimates were prepared for some water augmentation projects described herein, where it was possible to define a project in sufficient detail to provide an estimate of the project costs. The purpose for providing planning level costs is to compare the relative costs of different water augmentation project concepts. The cost estimates are presented in terms of a cost per acre-foot (AF) so that the relative costs of different water augmentation options can be compared to avoid bias. The project cost includes estimates of both capital and operating costs. At this planning level, the costs do not apply to any one specific site location or detailed project components. This cost accuracy corresponds to a Class 5 cost estimate according to the Association for the Advancement of Cost Engineering (AACE) and have an estimated accuracy ranging from -50% to +100%. These planning level costs are in 2019 dollars. The cost estimates include the estimated cost of infrastructure from the water source to the point that water is introduced into the municipal distribution system. For example, the cost components of a conceptual brackish groundwater desalination project include new wells, a new RO treatment facility, conveyance between the new wells and the new treatment facility, brine management systems, storage, and a pump station. Transmission mains between a treatment facility and the water distribution system are location specific and not included in these costs. Planning level costs are often presented as a "construction cost" or a "project cost."
A construction cost is the cost an owner would pay a contractor to construct the facility. A "project cost" is the cost that a City should budget in a Capital Improvement Program (CIP) for all the expenses associated with delivering the project. In addition to the construction cost, the project cost includes engineering design, construction management, city administrative costs, and a 10 percent contingency. Unless otherwise noted, all costs presented in this report are project costs as estimated and calculated by Carollo Engineers.

2.3.2 Water Augmentation by Planning Area

The specific needs of rural planning areas were considered in the evaluation. However, in many planning areas the opportunities for water augmentation are limited to implementing Best Practices, overcoming the impediments to water augmentation, and brackish groundwater desalination where the brackish groundwater exists. Table 3 presents the water augmentation options that are possible for each planning area. All planning areas can benefit from the Best Practices. Table 3 does not identify areas with additional groundwater supplies where groundwater may exist. Groundwater studies have not been completed to identify the amount of available groundwater and development does not exist in these areas.

Table 3 Water Augmentation Options by Planning Area

<table>
<thead>
<tr>
<th>Planning Area</th>
<th>Applicable Water Augmentation Category</th>
</tr>
</thead>
<tbody>
<tr>
<td>Apache</td>
<td>Best Practices: Agricultural Water Conservation, Enhancing Aquifer Storage, Reclaimed Water, Municipal Water Conservation</td>
</tr>
<tr>
<td>Basin &amp; Range Active Management Areas (AMA)</td>
<td>Brackish Desalination near Buckeye or Picacho</td>
</tr>
<tr>
<td></td>
<td>SRP-CAP Interconnect Facility (SCIF)</td>
</tr>
<tr>
<td></td>
<td>West Basin Alluvial Aquifers for allowable groundwater transportation</td>
</tr>
<tr>
<td></td>
<td>Modify Operation of the Roosevelt Dam to Use the Flood Control Space</td>
</tr>
<tr>
<td></td>
<td>Firm Water Supplies for Lower Priority Water Users</td>
</tr>
<tr>
<td></td>
<td>Best Practices: Agricultural Water Conservation, Enhancing Aquifer Storage, Reclaimed Water, Municipal Water Conservation</td>
</tr>
<tr>
<td>Bill Williams</td>
<td>Best Practices: Agricultural Water Conservation, Enhancing Aquifer Storage, Reclaimed Water, Municipal Water Conservation</td>
</tr>
<tr>
<td>Central Plateau</td>
<td>Brackish Desalination near Winslow</td>
</tr>
<tr>
<td></td>
<td>Best Practices: Agricultural Water Conservation, Enhancing Aquifer Storage, Reclaimed Water, Municipal Water Conservation</td>
</tr>
<tr>
<td>Cochise</td>
<td>Brackish Desalination</td>
</tr>
<tr>
<td></td>
<td>Best Practices: Agricultural Water Conservation, Enhancing Aquifer Storage, Reclaimed Water, Municipal Water Conservation</td>
</tr>
<tr>
<td>Colorado River Main Stem - North</td>
<td>Firm Water Supplies for Lower Priority Water Users</td>
</tr>
<tr>
<td></td>
<td>Best Practices: Agricultural Water Conservation, Enhancing Aquifer Storage, Reclaimed Water, Municipal Water Conservation</td>
</tr>
<tr>
<td>Colorado River Main Stem - South</td>
<td>Brackish Desalination near Yuma and Parker</td>
</tr>
<tr>
<td></td>
<td>Brackish Desalination near Wellton-Mohawk</td>
</tr>
<tr>
<td></td>
<td>Firm Water Supplies for Lower Priority Water Users</td>
</tr>
<tr>
<td></td>
<td>Best Practices: Agricultural Water Conservation, Enhancing Aquifer Storage, Reclaimed Water, Municipal Water Conservation</td>
</tr>
</tbody>
</table>
Table 3  Water Augmentation Options by Planning Area (continued)

<table>
<thead>
<tr>
<th>Planning Area</th>
<th>Applicable Water Augmentation Category</th>
</tr>
</thead>
<tbody>
<tr>
<td>East Plateau</td>
<td>Brackish Desalination near Concho</td>
</tr>
<tr>
<td></td>
<td>Best Practices: Agricultural Water Conservation, Enhancing Aquifer Storage, Reclaimed Water, Municipal Water Conservation</td>
</tr>
<tr>
<td>Gila Bend</td>
<td>Brackish Desalination</td>
</tr>
<tr>
<td></td>
<td>Best Practices: Agricultural Water Conservation, Enhancing Aquifer Storage, Reclaimed Water, Municipal Water Conservation</td>
</tr>
<tr>
<td></td>
<td>Best Practices: Agricultural Water Conservation, Enhancing Aquifer Storage, Reclaimed Water, Municipal Water Conservation</td>
</tr>
<tr>
<td>Hassayampa/Aqua Fria</td>
<td>Best Practices: Agricultural Water Conservation, Enhancing Aquifer Storage, Reclaimed Water, Municipal Water Conservation</td>
</tr>
<tr>
<td>Lower Gila</td>
<td>Brackish Desalination</td>
</tr>
<tr>
<td>Lower San Pedro</td>
<td>Brackish Desalination</td>
</tr>
<tr>
<td></td>
<td>Best Practices: Agricultural Water Conservation, Enhancing Aquifer Storage, Reclaimed Water, Municipal Water Conservation</td>
</tr>
<tr>
<td>Navajo/Hopi</td>
<td>Best Practices: Agricultural Water Conservation, Enhancing Aquifer Storage, Reclaimed Water, Municipal Water Conservation</td>
</tr>
<tr>
<td>Northwest Basins</td>
<td>Brackish Desalination near Red Lake</td>
</tr>
<tr>
<td></td>
<td>Best Practices: Agricultural Water Conservation, Enhancing Aquifer Storage, Reclaimed Water, Municipal Water Conservation</td>
</tr>
<tr>
<td>Roosevelt</td>
<td>Best Practices: Agricultural Water Conservation, Enhancing Aquifer Storage, Reclaimed Water, Municipal Water Conservation</td>
</tr>
<tr>
<td>Upper Gila</td>
<td>Brackish Desalination near Gila Valley</td>
</tr>
<tr>
<td></td>
<td>Best Practices: Agricultural Water Conservation, Enhancing Aquifer Storage, Reclaimed Water, Municipal Water Conservation</td>
</tr>
<tr>
<td>Upper San Pedro</td>
<td>Best Practices: Agricultural Water Conservation, Enhancing Aquifer Storage, Reclaimed Water, Municipal Water Conservation</td>
</tr>
<tr>
<td>Verde</td>
<td>Best Practices: Agricultural Water Conservation, Enhancing Aquifer Storage, Reclaimed Water, Municipal Water Conservation</td>
</tr>
<tr>
<td>West Basins</td>
<td>Best Practices: Agricultural Water Conservation, Enhancing Aquifer Storage, Reclaimed Water, Municipal Water Conservation</td>
</tr>
<tr>
<td>West Borderlands</td>
<td>Brackish Desalination</td>
</tr>
<tr>
<td></td>
<td>Best Practices: Agricultural Water Conservation, Enhancing Aquifer Storage, Reclaimed Water, Municipal Water Conservation</td>
</tr>
<tr>
<td>Western Plateau</td>
<td>Best Practices: Agricultural Water Conservation, Enhancing Aquifer Storage, Reclaimed Water, Municipal Water Conservation</td>
</tr>
</tbody>
</table>

Figure 2 illustrates the water augmentation possibilities in each planning area. The map does not specifically list Best Practices that can occur in all planning areas.
LONG-TERM WATER AUGMENTATION OPTIONS FOR ARIZONA | WATER AUGMENTATION STUDY

Figure 2 Water Augmentation Projects by Planning Area

Legend

WATER AUGMENTATION PROJECTS ASSOCIATED WITH SPECIFIC PLANNING AREAS

- Butler Valley
- Harquahala INA
- CAP Canal
- Water Resource Planning Areas

Interconnect
Modify operation of the Roosevelt Dam
Brackish Desalination

Data Sources:
Planning Areas, Groundwater Basin: ADWR
Rivers, River Basin, Street Map, State Boundaries: ESRI

Last Revised: July 30, 2019
M:\Client\ADWR\11028a.00\GIS\mxd\Deliverables\Draft Report\Figure 2 Water Augmentation Projects by Planning Area.mxd
Section 3

WATER AUGMENTATION OPPORTUNITIES

3.1 Ocean Desalination

Minute 323 entitled "Extension of Cooperative Measures and Adoption of a Binational Water Scarcity Contingency Plan in the Colorado River Basin" was entered into on September 21, 2017 and its development included delegates from the United States, Mexico and the International Boundary and Water Commission (IBWC). In Section IX. B of Minute 323, "New Water Sources Projects," opportunities exist for joint cooperative projects with the potential to increase delivery or exchange of Colorado River water benefiting both the United States and Mexico, which include the following projects:

- Binational Desalination Plant at the Pacific Ocean coast;
- Binational Desalination Plant in the New River;
- Binational Desalination Plant, Sea of Cortez;
- Reuse of the effluent from the Mexicali Valley wastewater treatment plants in wetlands or riparian restoration of the Colorado River; and
- Reuse in the United States of South Bay International Wastewater Treatment Plant effluent.

The Minute directed the formation of a Binational Desalination Work Group comprised of Federal, State, and water agencies from the United States and Mexico which would study potential new water sources projects. The next action tasked to the Binational Desalination Work Group is the completion of a study of water desalination opportunities in the Sea of Cortez. The study is a preliminary investigation to identify the range of possibilities for potential future development of binational desalination opportunities that provide benefits to water users in the United States and Mexico. A consultant to conduct the study has been selected and the project is currently underway. The consultant's team consists of engineering, desalination, and environmental experts from Mexico and the United States. They will evaluate technical and environmental issues that include:

- Local and regional current and future unmet water needs in Sonora and Baja California, Mexico, and the lower Colorado River Basin, United States;
- Various desalination technologies that could be applicable in the region;
- Potential desalination opportunity locations along the Sonoran coast between Puerto Peñasco and Puerto Libertad; and
- Possible impacts to the marine environment, flora and fauna.

The study will include recommended desalination concepts to consider for possible additional investigation and is scheduled to conclude in 2020.

This Binational Desalination Work Group is the organizational vehicle for Arizona to consider opportunities for desalination projects with Mexico.
3.2 Brackish Groundwater Desalination

Brackish groundwater is located in numerous places in Arizona and could provide an important water supply when the cost of desalinating this groundwater aligns with a willingness to pay.

Brackish desalination is the treatment process to remove total dissolved solids (TDS) from brackish sources of groundwater. TDS is more commonly referred to as "salt", which is a mixture of dissolved inorganic salts consisting principally of sodium, calcium, magnesium, potassium, chlorides, sulfates, and bicarbonates. Brackish groundwater contains TDS concentrations between 1,000 and 10,000 milligrams per liter (mg/L). EPA provides guidance that TDS in drinking water should be within range of 500 mg/L.

Brackish groundwater desalination would occur in areas of the state where brackish groundwater exists and could be pumped and treated for beneficial use. Studies have been conducted to identify areas of the state where brackish groundwater exists (https://pubs.er.usgs.gov/publication/fs20183010), and additional studies may identify additional locations of brackish groundwater. Water planning areas that may benefit from brackish groundwater development include: Basin and Range, Gila Bend, Navajo/Hopi, Cochise, Lower Gila, West Borderlands, Colorado Main Stem South, Central Plateau, Eastern Plateau, Northwest Basins, and Upper Gila. Locations of brackish groundwater do not necessarily coincide with existing population centers.

The volume of brackish water that may be pumped varies by location. One area with the greatest potential for brackish groundwater development is the Buckeye waterlogged area, which is located along the Gila River in parts of Buckeye, Goodyear, Avondale, and Phoenix. Brackish groundwater in these areas is currently used to irrigate salt tolerant crops. Some estimates place the water yield potential as high as 50,000 acre-feet per year (AFY) (https://www.usbr.gov/lc/phoenix/programs/cass/pdf/Phase2/4CBrackishGroundwaterAppendix-C.pdf). Brackish groundwater in the Yuma area is expected to exceed 10,000 AFY. In most of the other areas with brackish groundwater, the sustainable yield is expected to be more in the range of 6,000 – 10,000 AFY in each location where brackish groundwater is developed.

Treatment processes may involve distillation, reverse osmosis (RO) (see Figure 3), or electro-dialysis reversal (EDR). RO is the most common treatment method in the United States to remove TDS as well as other undesirable constituents. However, the RO treatment process creates a brine stream that must be managed and it is the cost of managing this brine stream that presents the largest cost hurdle in developing brackish groundwater as a potable water supply. Major cost components in managing the brine stream are energy and land.

Brackish groundwater is not currently being implemented on a large scale because other water supplies are currently less expensive. However, the price of water in Arizona is expected to increase, and research into less expensive methods of managing brine are ongoing, so brackish groundwater desalination is expected to become economically viable in the future. Brackish groundwater can be managed currently in the following ways:

- Brine evaporation ponds (see Figure 4)
- Discharge to an industrial facility with cooling towers
- Deep well injection (see Figure 5)
• Brine has been discharged to sanitary sewer systems where the volume of brine is very small relative to the volume of wastewater being treated
• Thermal Brine Concentration (see Figure 6)
• Vacuum Membrane Distillation

Figure 3  Reverse Osmosis Treatment Facility at the Bullard Water Campus City of Goodyear, AZ

Figure 4  Brine Evaporation Ponds
Figure 5  Deep Well Injection Facility

Figure 6  Thermal Brine Concentration Facility
Arizona’s laws governing groundwater currently treat all groundwater as a potential drinking water source, so obtaining regulatory approval to degrade groundwater quality with deep well injection is expected to be difficult, but not impossible to permit for brine disposal. Permitting would require groundwater hydraulic modeling to determine where brine can be stored safely, and would involve pilot testing of injection wells and monitoring. The following regulatory issues would need to be addressed:

1. Partner with other water users and ADEQ to develop standards, protocols, and best management practices that applicants can use to develop a permitting process that is in compliance with the Arizona Aquifer Protection Program (APP).
2. Partner with ADWR to develop and/or modify as appropriate injection well construction and testing standards and evaluate suitable geologic environments.
3. Participate in Environmental Protection Agency’s (EPA) underground injection control (UIC) primacy stakeholder process and ensure that implementation of combined APP/UIC program provides for deep brine injection under appropriate conditions.

With the exception of the Buckeye waterlogged area, other sources of brackish groundwater are not located in an AMA that requires groundwater replenishment. There is currently a groundwater replenishment exemption for groundwater pumped from the Buckeye waterlogged area that expires at the end of 2024. Unless this exemption is extended, the Central Arizona Groundwater Replenishment District (CAGRD) groundwater replenishment rates will need to be paid via property taxes to water users, which significantly increases the cost of developing and treating Buckeye Waterlogged Area groundwater for potable use. Within an AMA, brackish groundwater is not a new water source that could be added to a portfolio for an Assured Water Supply, but a groundwater source that is currently not used because of the cost.

The infrastructure needed to develop a brackish groundwater supply includes the following:

- Multiple wells located near a treatment facility
- Raw water mains between the wells and the treatment facility
- Treatment facility that primarily consists of RO equipment
- Potable water storage tanks
- Pump station
- Transmission main to the location of water demands
- Brine management facility

Funding for a brackish groundwater desalination facility would likely come from the same funding sources municipalities use for other water infrastructure. There may be opportunities for communities to jointly fund a facility where it can be located to economically serve both communities. The cost to develop a brackish groundwater desalination facility for a TDS level of 3,000 mg/L that includes wells, treatment, storage, pumping, and brine treatment may vary between $1,500 and $2,000 per AF.

The permits that may be needed to construct a brackish groundwater desalination facility are the same as any other groundwater production and treatment facility, and are listed in Appendix A.
Brackish Groundwater References:

1. [This post provides a short description of brackish water's contribution to Arizona's groundwater resources (more than 600 million AF stored underground), and its associated advantages/challenges.]
   https://elmontgomery.com/will-desalinated-brackish-groundwater-become-arizonas-next-big-supply-source/

2. [This article highlights brackish water desalination as an important component of Arizona's water portfolio. Desalination helps reduce water scarcity and salinity problems especially due to salt loading by the CAP canal. It also describes the challenges attributed to the technology, including brine disposal, energy requirements, environmental impacts, infrastructure costs, and regulatory uncertainty.]
   https://wrrc.arizona.edu/sites/wrrc.arizona.edu/files/Arroyo_2011.pdf

3. [This study examines important requirements to be addressed during the addition of brackish groundwater to the central Arizona's water resources portfolio. These include regulatory codes, water quantity and quality, and treatment processes.]

4. [This report reviews the Central Arizona Salinity Study, which evaluated salinity problems due to the importation of salts into central Arizona and its potential solutions. In the first phase of the study, modeling results present the high cost associated with salinity issues. The second phase evaluated a variety of potential alternatives to manage salinity and provide recommendations in regard their effects to central Arizona and associated challenges of implementation.]
   https://www.usbr.gov/lc/phoenix/programs/cass/pdf/Phase2/1PhaseIIExecutiveSummary.pdf

5. [This presentation describes the pros and cons associated with the potential areas in Arizona where brackish water desalination can be implemented. These areas include Buckeye Area, Gila Bend Basin, Yuma Mesa/Yuma Valley, Picacho Basin, Winslow-Leupp Area, and Willcox Playa Area. It also discusses the advantages/challenges of brine disposal via deep injection.]

3.3 Groundwater Transfers from the Harquahala and Butler Valleys to Basin and Range AMAs

Arizona State Statutes (A.R.S. § 45-553 and 45-554) allow groundwater from the Butler Valley basin and the Harquahala Irrigation Non-expansion Area (INA) west of Phoenix to be withdrawn and transported to the Basin and Range AMAs for use via the CAP Canal. The McMullen Valley also has groundwater that can be withdrawn and transported but State Statute (A.R.S. § 45-552) would need to be amended to broaden the land ownership requirement. Water in these basins is currently being used for agriculture, primarily alfalfa, but most land owners expect to develop groundwater supplies and sell the groundwater in the future. Only the State of Arizona and political subdivisions of the State (i.e., cities and towns) may transport groundwater from the Harquahala INA to an AMA. In the Harquahala INA, the volume of groundwater that may be transported by an eligible entity is limited to an annual average of 3 AF/acre of land owned by the entity in the INA that is eligible to be irrigated, and the groundwater may not be withdrawn from a depth greater than 1,000 feet. The Director of ADWR may allow an eligible entity to transport more than an annual average of 3 AF/acre if the Director determines that the
withdrawal of the groundwater will not unreasonably increase damage to residents of surrounding land and other water users in the INA, or that the damage will be mitigated. The 1000 foot depth limit for withdrawals would still apply. In addition, CAP water previously stored in the INA can be recovered for use. Planning and development to extract and transport groundwater is underway by the several parties that own land in Harquahala, and similar projects could be implemented in Butler Valley Water from the Harquahala basin can be transported to the Basin and Range AMAs via the CAP Canal as long as an agreement is made with the CAP to wheel the water and comply with CAP requirements, including water quality requirements and the National Environmental Protection Act (NEPA). Groundwater transported to the Basin and Range AMAs would provide an additional water supply for municipalities. It also can be used as a way to firm lower priority Colorado River water rights if a provider has purchased enough capacity in the Harquahala infrastructure delivery system.

A.R.S. § 45-559 provides that an eligible entity may not withdraw groundwater from a well drilled after September 21, 1991 for transportation into an AMA unless the Director determines that the withdrawals will not unreasonably increase damage to surrounding land or other water users from the concentration of wells.

The water supply potential of the Harquahala INA has not been determined by ADWR. Legislation was proposed during the 2019 Arizona legislative session to lower the groundwater withdrawal limit from 1,000 feet to 1,500 feet in the Harquahala INA, but the legislation was not enacted.

Financing development of Harquahala water supplies would be through the same financial sources as are currently used for financing other municipal water facilities.

The technology required to develop groundwater basins is well established and no different from the technology used by municipalities throughout Arizona.

The following infrastructure components would be needed to develop Harquahala water supplies:

- Wells in the Harquahala basin
- Transmission mains to the CAP canal
- Ground storage tanks
- Pump stations
- Discharge facility to the CAP canal.
- CAP canal diversion to withdraw at the point of use
- Water treatment plant, or
- Spreading basins and wells to recharge and withdraw the water

Partnerships that would be required for this water augmentation project include:

- Central Arizona Water Conservation District (CAWCD) (System Use Agreement)
- Landowners in the Harquahala basin.
- Investors (for infrastructure)
- The State of Arizona or political subdivisions of the State in the AMAs
Funding sources would be the same ones that municipalities use for other water infrastructure. The cost of developing a Harquahala basin water supply is approximately $1,800 - $2,000/AF including the cost from project proponents.

Permitting requirements are listed in Appendix A.

3.4 Long-Term Water Augmentation Options that were Eliminated

At times in the past, water augmentation by importing water from other states has been discussed (See Colorado River Basin Water Supply and Demand Study, US Bureau of Reclamation, December, 2012). These augmentation ideas were raised and then discarded as not practical, not legally possible, or financially infeasible. The efforts of the Committee and this Project are to focus on implementable water supply solutions. Table 4 lists the reasons that specific out of state water augmentation ideas were discarded.

Table 4  Long-Term Water Augmentation Concepts that were Discarded

<table>
<thead>
<tr>
<th>Large Water Augmentation Source</th>
<th>Reason For Elimination</th>
</tr>
</thead>
<tbody>
<tr>
<td>Snake River or other river in the Columbia River basin</td>
<td>• Current law makes it illegal to take water from the Columbia River basin.</td>
</tr>
<tr>
<td></td>
<td>• Other than some high spring runoff, Snake River water is heavily committed to</td>
</tr>
<tr>
<td></td>
<td>agricultural use</td>
</tr>
<tr>
<td>Bear River in Utah</td>
<td>• This river is committed to development in Utah along the Wasatch Front.</td>
</tr>
<tr>
<td></td>
<td>• The river is not large enough to provide a significant amount of water to Arizona</td>
</tr>
<tr>
<td>Rio Grande River</td>
<td>• There are already many conflicts over water in this river.</td>
</tr>
<tr>
<td></td>
<td>• Water supplies are not sufficient</td>
</tr>
<tr>
<td>Snowpack on the Colorado Front Range</td>
<td>• Denver has already obtained most of the water rights that could be available.</td>
</tr>
<tr>
<td>Reclaimed water from Pacific coast cities in Oregon and Washington, delivered to Nevada and then to Arizona via exchange</td>
<td>• High costs</td>
</tr>
<tr>
<td></td>
<td>• Very difficult to permit across multiple states</td>
</tr>
<tr>
<td>Floodwaters from the Missouri River</td>
<td>• Very high costs for a seasonal water supply</td>
</tr>
<tr>
<td></td>
<td>• Very difficult to permit across multiple states</td>
</tr>
</tbody>
</table>
Section 4

BEST PRACTICES THAT IMPROVE WATER USE EFFICIENCY

The following four Best Practices help to utilize existing water supplies more effectively. Although they do not provide a new supply, these practices extend existing supplies, providing the net effect of a new supply. Municipal water conservation and reclaimed water utilization have the potential in some communities to significantly extend the time until additional water supplies are required. The cost of best practices that improve water use efficiency is significantly less than new water augmentation options, so Best Practices are likely to be implemented before the water augmentation options are implemented. Best Practices can also be implemented in all of the planning areas and can therefore provide benefits statewide.

4.1 Agricultural Water Conservation

Agricultural water conservation has been an integral part of Arizona’s agriculture industry for decades. Water conservation is achieved using multiple approaches to reduce water use either on the farm or through an irrigation district or company.

Agricultural water conservation includes one or more of the following approaches to reduce agricultural water use:

1. Implement more efficient irrigation methods that irrigate based on actual crop water use.
2. Reduce evaporation loss by modifying center pivot design and performance in the following ways:
   a. Install more drop hoses per foot.
   b. Replace flat or groove pads with bubblers that distribute the water in a larger particle.
   c. Lengthen drop hoses so the water falls closer to the ground.
   d. Slow down the pivot’s movements to maintain the same permeation levels.
3. Grow low water use crops when possible.
4. Line canals.
5. Line ditches.
6. Construct check dams and retention dams in sensitive pastures to prevent runoff, increase recharge, and reduce erosion.
7. Cover stock tanks to reduce evaporation.
8. Land fallowing.
9. Irrigation scheduling.
10. Laser level fields.
11. Sprinkle irrigate to germinate vegetable seeds.
12. Implement drip irrigation when possible.
13. Grow crops at times other than during peak summer temperatures.
15. Expand use of the Irrigation Management Services program (IMS) to monitor on-farm practices and determine the most effective techniques for each farm to achieve maximum irrigation efficiency.

Agriculture is a for profit enterprise so agricultural conservation practices must be profitable for the farmers or subsidized by others. The farmer’s water allocation is fixed, so reductions in water use that a farmer obtains allows the farmer to irrigate more of his own farmland, but does not free up water for another user. The crops grown throughout the state vary, and the types of water sources and conveyance mechanisms also vary, so the water conservation methods and benefits need to be specifically adapted to each farm or irrigation company.

Technology can play a role in increasing irrigation efficiency where soil moisture measurements and automated irrigation controls can provide efficiency improvements. Some farming operations are quite advanced and may have done all that is possible to economically reduce water use.

With so many different ways to implement agricultural conservation it is not possible to be prescriptive of what type of water conservation is best for a specific situation, estimate the water savings or the cost of implementing agricultural water conservation.

Long-Term Water Augmentation Committee members provided the following examples of agriculture efficiency projects:

- Since 1970, agriculture in Yuma County has doubled its winter vegetable crop production acreage and simultaneously reduced water delivery to farms by 20 percent. The 20 percent reduction in water delivery to farms coupled with other use reductions and unused entitlement has resulted in about 140,000 of annual augmentation to Pinal County agriculture. Methods used to obtain this increase in water use efficiency include:
  - The use of bolas to smooth the sides of furrows
  - The use of laser and satellite leveling to achieve a level basin
  - The use of higher volume gates
  - The use of multiple irrigation methods on the same crop.
- Hauser and Hauser Farms worked with The Nature Conservancy to converted 34 acres of flood irrigation to subsurface drip irrigation. Subsurface drip is between 40 percent - 60 percent more efficient than flood irrigation (Figure 7).
- Speck Farms worked with The Nature Conservancy to grow 30 acres of malt barley at Shield Ranch for Sinagua Malt. Malt barley shifts the water needs to the spring and uses less water than traditional crops, leaving more water in the Verde River during low-flow summer months (Figure 8).
- The Wingfield 1 Ditch partnered with The Nature Conservancy to pipe a 3,350-foot section of their irrigation ditch. This reduced seepage loss in the ditch and left more water in West Clear Creek (Figure 9).
• In Graham County, water use efficiencies on center pivot irrigation systems have been improved by up to 150 gallons per minute (gpm) per system by implementing the following practices (Figure 10):
  – Installing more drop hoses per foot
  – Replacing traditional flat pads or groove pads with bubblers, which distribute the water in a larger particle
  – Lengthening the drop hoses so that the water falls closer to the ground
  – Slowing down the pivot's movement to maintain the same permeation levels.

• In Pinal County, the Irrigation Management Services program (IMS) monitors on-farm practices and determines the most effective techniques for the farms to achieve maximum irrigation efficiency. The IMS determinations assist the 174 farms who participate in the Irrigation Best Management Practices program, spanning 89,200 acres.

• In Mojave County, the following practices have been implemented to reduce water use:
  – Check dams and retention dams installed in sensitive pastures has prevented water runoff, allowing water to recharge the aquifer and reducing soil erosion
  – Covered stock tanks reduce evaporation, saving as much as 1/2 to 1 inch of water in a tank per day during the summer

Figure 7  Subsurface Drip Irrigation on Carrots at Park Central Farms in the Verde Valley
(Photo courtesy of The Nature Conservancy)
Figure 8  Soil Moisture Monitoring on Malt Barley at Shield Ranch in the Verde Valley (Photo courtesy of The Nature Conservancy)

Figure 9  Wingfield 1 Piping Project, Phase 2, Verde Valley (Photo courtesy of The Nature Conservancy)
Figure 10  Traditional center pivot sprinkler heads are shown, which create a fine mist. Farmers in Graham County have been able to save up to 150 gallons per minute by replacing these with heads that create larger water particles.

The following references provide additional information on agricultural water conservation:

1. [The website provides a description of irrigated agriculture in Arizona, and its associated conservation requirements, best management practices. It also provides software and application tools to enhance efficiency and further educational information.]
   http://www.azwater.gov/AzDWR/StatewidePlanning/Conservation2/Agriculture/

2. [The presentation describes the ADWR’s agricultural conservation programs such as Base Program, BMP Program, and Historic Cropping Program.]

3. [The article describes the background and profile of irrigated agriculture in Arizona and its importance to the state. It also discusses the groundwater regulations associated with the use, along with its reliance on Colorado River Water, and agricultural water conservation.]
   https://wrrc.arizona.edu/sites/wrrc.arizona.edu/files/attachment/Arroyo-2018-revised.pdf

4. [Arizona Water Atlas provides an overview of water management and planning in the state; discussion on water budgets for planning purposes; a summary water resource characteristics and its attributed data sources and methods of analysis; information on water law and management, and Indian water rights claims and settlements.]
4.2 Enhance Aquifer Storage

Aquifer recharge is the process of storing renewable water resources in the aquifer for later use, to manage and preserve the aquifer. Recharging water with the intention of adding to an aquifer in Arizona and accruing credits is a regulated activity that requires a permit from ADWR.

Recharge can be achieved through managed projects such as within a riverbed or constructed projects such as detention basins, rapid infiltration basins (See Figure 11 and Figure 12) or injection wells.

Figure 11  Palominas Flood Control and Recharge Project that is part of the Cochise Conservation and Recharge Network (Photo courtesy of Cochise County)
Water that can be recharged includes the following:

1. Reclaimed Water
2. Surface Water supplies
3. Urban Enhanced Runoff (UER)
4. Groundwater transported into an AMA from the Harquahala and Butler Valleys
5. CAP Water

Aquifer recharge using reclaimed or CAP water within an AMA can be used to accrue long-term storage credits (LTSC). Surface water can be stored as well, but must be used in the month the water is stored. Reclaimed water recharge outside of an AMA can accrue credits in addition to enhancing the aquifer, providing benefits to water users.

One type of water supply that can be stored is Urban Enhanced Runoff (UER), which is the additional portion of storm water generated from water running off urbanized surfaces such as streets, parking lots, and rooftops. State policies are needed to protect surface water rights and also allow for use of UER, defined as storm water generated by the presence of impermeable surfaces that did not exist when surface rights were established. It would be helpful to have clarification from ADWR regarding how to quantify and measure UER that can be captured for recharge. State policies should be considered to address whether it is possible to allow for use of UER while still protecting the supplies for existing surface water rights. UER currently cannot be
stored for credits. Re-purposing flood control infrastructure for water capture and recharge may reduce the cost of recharge for UER.

Enhancing aquifer storage is applicable in planning areas where:

1. Pre-existing surface runoff rights are not present or where water supplies for those rights cannot be protected, UER might be an option. Yield is expected to be sporadic but could benefit declining aquifers. Its value depends upon the volume that can be produced.
2. Recharge can help sustain aquifer levels or base flow in a river or riparian habitat in alluvial aquifers.
3. Recharge can help to sustain groundwater levels for private wells in rural areas.

Aquifer storage can occur in any planning area, but may be particularly useful in the following planning areas: Navajo/Hopi, Arizona Strip, Northwest Basins, Western Plateau, West Borderlands, Cochise, Upper San Pedro, Verde, and Northwest Basins.

Financing would be through the same mechanisms used by municipalities, i.e., rated, bonds, and WIFIA funding. Funding may come through more than one agency. Grants from federal agencies and non-governmental organizations could also fund these types of multiple benefit projects. The cost of aquifer storage with well recovery and possibly treatment may vary between $800 and $1,500 per AF depending on the type of groundwater treatment that may be required. Aquifer storage alone may cost between $200 and $400 per AF. The volume of water to be recharged at any one location from storm water is highly variable. If reclaimed water is used, the volume of water that can be stored is up to approximately 30 percent of the potable water supply of the community.

Components of a recharge facility may include:

- Water capture or delivery infrastructure
- Spreading basins
- Dry wells for storm water recharge

Partners in recharge facilities are varied and could include:

- Flood control districts
- Irrigation districts
- Wastewater utilities, neighboring communities
- Wholesale water providers
- Cities
- Non-Governmental Organizations (NGOs) for environmental flows

The permitting requirements are listed in Appendix A.
The following technical issues may need to be addressed when implementing an aquifer recharge project:

1. Infiltration rates can diminish if basins are not properly designed, operated, or maintained.
2. Adoption of established modeling software that estimates interactions (inflows & outflows) between surface and ground water may be difficult because existing regulations related to groundwater management have relied upon older software that does not account for interactions between surface and ground water. As an example, the Australian Water Balance Model (https://wiki.ewater.org.au/display/SD41/Australian+Water+Balance+Model+%28AWBM%29++SRG) is a program that considers the interaction between groundwater and surface water, and therefore could be adopted for use.
3. Monitoring and measuring recharge
4. Stormwater may be polluted with chemical and microbial contaminants. The public should be educated about steps taken to clean storm water before it is recharged into the aquifer, how water quality of the groundwater is monitored, and what the benefits are regionally to recharging the aquifer.

References:

1. [In this study, information on water runoff from stormwater and agriculture were estimated.] https://repository.arizona.edu/bitstream/handle/10150/314278/wrrc_170.pdf?sequence=1
2. [This post discusses the use of dry wells for storm water management and where it is being implemented. It also recommends further research on water quality impacts and O&M Best Practices associated with this stormwater management approach. https://wrrc.arizona.edu/dry-wells-for-stormwater-mgmt
3. [In this study, ADWR identified possible strategies and projects aiming to reduce the long-term imbalance between available supplies and projected water demands over the next 100 years (3 million AF). Some strategies include addressing Indian and Non-Indian water rights claims, continuing conservation and increasing the reuse of reclaimed water, expanding monitoring and reporting of water use, analyzing the importance of in-state of water transfers, and exploring the idea of supply importation (desalination). Additionally, applicable areas where the strategies can be implemented are provided.] http://www.azwater.gov/AzDWR/Arizonas_Strategic_Vision/documents/OpportunitiesandChallengesforArizona.pdf

4.3 Reclaimed Water

Reclaimed water, sometimes also referred to as recycled water, is wastewater that is treated to a high standard that makes this water suitable for additional uses. Reclaimed water projects are typically implemented by municipalities or private utilities with the goal of beneficially using reclaimed water in a manner that provides the highest and best use for the entity generating the reclaimed water.
Arizona is a leader in reclaimed water use in many parts of the state. Reclaimed water use is very prevalent in the AMAs where reclaimed water is an important part of the water supply portfolio used to obtain a designation of assured water supply. The practice of water reuse is potentially applicable in all Planning Areas and has the most immediate potential where mechanical wastewater treatment facilities already exist.

Reclaimed water projects can be implemented anywhere in the state where a wastewater treatment facility exists. Reclaimed water projects can be combined with other augmentation project technologies such as aquifer storage of surface water supplies. Recovery wells can be permitted to recover reclaimed water credits, or other recharged surface water.

Reclaimed water systems may be difficult to implement where a centralized wastewater collection system is too expensive to install due to distance between properties in a service area. However, where centralized wastewater collection and treatment already exists, the ability to maximize use of reclaimed water will be dictated by local conditions such as distance and demand of non-potable applications, suitability of aquifers for recharge, surface water supply augmentation, and feasibility of implementing direct potable reuse into an existing centralized potable water distribution system.

Reclaimed water systems are valuable because they can recover up to approximately 30 percent of the water delivered by a potable water system. Reclaimed water systems, along with UER provide a water source that increases with an increase in population. Reclaimed water systems can also help to reduce groundwater pumping.

Because sewer rate payers have already paid for the wastewater to be treated to a suitable water quality for discharge to the environment, the incremental cost to produce reclaimed water is similar to or less than the cost of water that municipalities pay for other water supplies.

Reclaimed water systems are usually financed by a single municipality using the same financing mechanisms that cities use for other water infrastructure. The cost of directly reusing reclaimed water for non-potable uses may be as low as $200/AF. The cost of reclaimed water aquifer storage and recovery may vary between $800/AF and $1,500/AF depending on the type of groundwater treatment may be required after the stored water is recovered. The cost of a direct potable reuse (DPR) water supply beyond the cost of wastewater treatment may vary between $1,000 and $1,800 per AF depending on the type of treatment that may be required, and whether or not brine management needs to be a component of the cost.

Reclaimed water can be used in a variety of ways, including the following:

- Aquifer Recharge (See Figure 12 and Figure 13)
- Potable Reuse
- Non-Potable Reuse, also called Direct Reuse, and is water delivery for industrial or irrigation applications.
- Voluntary In-State Exchanges
- Grey Water Use
The tasks to implement reclaimed water systems may vary widely depending on the needs and circumstances of a community, and include the following components:

- Upgrade lagoon treatment facilities to centralized or decentralized mechanical treatment to maximize reclaimed water production
- Convert on-site septic systems to centralized mechanical treatment
- Beneficially reuse reclaimed water via DPR, indirect potable reuse (IPR), or direct reuse.

Reclaimed water project partnerships may include the following:

- Regional wastewater collection and treatment authorities, neighboring communities, irrigation districts, investor owned utilities, Indian tribes and public/private partnerships.
- Wastewater utilities, developers and cities for replenishing the aquifer (or accruing LTSCs), NGOs for environmental flows and industry.
- Federal government - Water Infrastructure Finance Authority (WIFA)

The permitting requirements for reclaimed water are listed in Appendix A. One way that the permitting process can be improved is to more effectively allow agencies to augment surface water supplies or groundwater supplies under the influence of surface water using reclaimed water.

Recent regulatory changes provide significantly increased opportunities for using reclaimed water. The prohibition of making use of reclaimed water as source for drinking water has been removed from Arizona rules. However, rules are currently in development for the implementation of direct potable reuse. Rules are in place for implementing direct delivery of reclaimed water for non-potable purposes, and indirect potable reuse through groundwater replenishment.
Recent changes made in 2019 legislation:

1. 2025 sunset date for storing reclaimed water and accruing LTSCs was repealed.
2. 95 percent credit for reclaimed water recharged at *existing* managed USF (a 50 percent credit was allowed prior to the change).

LTSCs accrued after January 2019 at an existing reclaimed water managed USF can be used to demonstrate assured or adequate water supply.

Implementing a reclaimed water system requires education of policy holders and the general public. Regardless of implementation method, reclaimed water use requires education of the public. Even though water reuse is practiced successfully in thousands of locations throughout the U.S., local demonstration is typically necessary for full buy-in by the rate payers. Public education campaigns are needed to change the perception of reusing water, particularly in DPR applications.

Determining who pays and who benefits from reclaimed water can become a social justice issue if the reclaimed water supply benefits only a few users. For example, if reclaimed water, which is a drought resistant supply, was dedicated to an irrigation system, then during a drought irrigation would not need to be curtailed even if a more important water use was curtailed because it receives water from a drought sensitive source. Reclaimed water use strategies should be planned so that the water can benefit the entire community.

The following technical issues may need to be addressed with a reclaimed water project:

1. Regardless of which method of implementation is pursued, operators need to be adequately trained and certified. For higher technology solutions, more rigorous qualifications for operators will be required.
2. Infrastructure standards, review, and cross connection control needs to be integrated into the business practices of the authorizing utility or jurisdiction.
3. If non-potable reuse is to be implemented, essentially a new utility will be established and will need to be supported by appropriate equipment, operators, billing systems, and construction review and inspections.
4. Costs to upgrade treatment facilities to meet to water quality needs of the end use of the reclaimed water can be high, especially for small cities and towns.

Reference:

1. [This report provides a guidance framework for DPR in Arizona. This includes recommendations on important facets of DPR that need to be specifically addressed in the development of regulations in Arizona for DPR to provide public health protection.](https://watereuse.org/wp-content/uploads/2018/02/NWRI-Guidance-Framework-for-DPR-in-Arizona-2018.pdf)

### 4.4 Municipal Water Conservation

Municipal water conservation is the practice of finding ways to use less water with existing customers, or to establish standards for new customers that result in a lower water use. The goal of water conservation strategies related to augmentation efforts is a sustained reduction of water demand.
Municipal water conservation can include a variety of efforts aimed to reduce water consumption. The water conservation section of the ADWR website contains information on multiple approaches to water conservation. Table 5 lists possible water conservation strategies. Many municipalities already have a water conservation program in place that includes some of the water conservation strategies in Table 5.

<table>
<thead>
<tr>
<th>Table 5</th>
<th>Water Conservation Strategies</th>
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<tbody>
<tr>
<td><strong>Outreach Programs</strong></td>
<td><strong>Conservation Services</strong></td>
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<tr>
<td>• Local/regional messaging programs</td>
<td>• Residential audits</td>
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<tr>
<td>• Community presentations to increase awareness</td>
<td>• Landscape consultations</td>
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<tr>
<td>• Market surveys/needs assessments</td>
<td>• Water budgeting</td>
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<td></td>
<td>• Interior retrofit programs</td>
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<td></td>
<td>• Customer high water use notification and resolution</td>
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<td>• Water waste investigations</td>
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<td></td>
<td>• Leak detection and correction</td>
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<td></td>
<td>• Meter repair/replacement</td>
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<td></td>
<td>• Comprehensive water system audit</td>
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<tr>
<td></td>
<td>• Water use plan for large users</td>
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<tr>
<td><strong>Educational Programs</strong></td>
<td><strong>Conservation Ordinances</strong></td>
</tr>
<tr>
<td>• Adult education/training programs</td>
<td>• Low water use landscaping requirements</td>
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<tr>
<td>• Youth conservation/education programs</td>
<td>• Water waste ordinances</td>
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<tr>
<td>• New homeowner landscape information</td>
<td>• Plumbing code requirements</td>
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<tr>
<td>• Xeriscape demonstration garden</td>
<td>• Limitations on water features, landscaping, and turf</td>
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<tr>
<td>• Distribute water conservation materials</td>
<td>• Landscape watering restrictions</td>
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<td></td>
<td>• Retrofit upon resale requirements</td>
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<td></td>
<td>• Landscape water-use efficiency standards</td>
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<tr>
<td><strong>Incentive Programs and Services</strong></td>
<td><strong>Conservation rate Structure and Curtailment Tariff</strong></td>
</tr>
<tr>
<td>• Gray water and storm water use</td>
<td>• Conservation - Tiered water rates</td>
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<tr>
<td>• Water harvesting</td>
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<tr>
<td>• Recycle car wash water</td>
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<tr>
<td>• Rebates for efficient toilets, efficient appliances, gray water, water harvesting, landscape conversion rebates</td>
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<tr>
<td>• Implement smart irrigation technology</td>
<td></td>
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<tr>
<td>• Pilot a new initiative, project, or program to increase water conservation</td>
<td></td>
</tr>
<tr>
<td>• Water loss reduction measures on the supply side of the water system</td>
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</tbody>
</table>
Municipal water conservation goals may be achieved through policy, incentives, and education programs. Municipal water use means "all non-irrigation uses of water supplied by a city, town, private water company, or irrigation district." The word "irrigation" refers to the use of water for agriculture, and not to the watering of lawns, golf courses, and school grounds, and is addressed in Agricultural Water Conservation.

Water conservation is applicable for any municipality in any planning area where water use is high enough to benefit from water conservation. A municipality does not need to implement all water conservation strategies. Water conservation potentially applies to all planning areas.

Water conservation is a very flexible strategy that can be combined with other augmentation strategies. Water conservation improves with improvements to technology and can be easily tailored to local conditions. One of the most effective ways to conserve water is to implement landscaping policies for new developments that limit the amount of turf. It is easier to design water conservation into a new development than to retrofit an existing development. Figure 14 presents several homes using xeriscaping to reduce outdoor water use.

The amount of water that can be conserved varies widely depending on current practices. Savings can vary from a few percentage points to 30 percent of the potable demand.

Individual homeowners can pay for most improvements and in many cases will recover their investment in 1 - 3 years in lower water bills. Incentives provided by water providers have been known to accelerate the rate of water conservation, but increasing levels of water conservation have been occurring in Arizona for years at a more gradual rate, so incentives are not considered to be necessary unless a rapid drop in water use is required. The cost of implementing water conservation depends on the water conservation measure, but can vary from negligible to up to $1,100/AF for some rainwater capture systems.
Communities may partner with other organizations in implementing a water conservation program, including: Community centers, libraries, parks & recreation facilities, science clubs, and agricultural cooperatives.

The following political challenges may need to be overcome to strengthen water conservation programs:

- The development community may view lush landscaping as an important amenity for selling homes and may therefore resist outdoor conservation measures even when the water supply for the development is not sustainable.
- Local policy makers will need to understand the reasons why municipal conservation is necessary.
- Changes to water rate structures may be necessary to incentivize water conservation.
- Conservation may be at odds with revenue needed for some water providers unless rate structures adjust to consider conservation.
There may be resistance to conservation by existing residents who have never had to conserve water in the past. Public education may be necessary through community websites, printed information, workshops, and water audits. Equity issues with incentive/rebate programs may be a concern in some communities, depending on how the incentives are financed. Conservation fees collected by all customers being used as rebates for some may not be seen as equitable.

The following technical challenges may need to be addressed when implementing a conservation program:

- Modifications to local plumbing codes may be necessary for full implementation.
- Building permit reviewers will need to understand the new codes to ensure enforcement.
- Adequate water metering and frequency to assess impacts of municipal water conservation.

References:

1. [This website provides the conservation requirements, water conservation efforts inside and outside Arizona’s AMAs, and resources to assist water resource planners/providers] http://www.azwater.gov/azdwr/StatewidePlanning/Conservation2/Planners/documents/IntrotoSummaryofConservationPrograms4_26_10.pdf
2. [This website provides some conservation information by topic for the public relevant to landscaping, technologies, educational tools, water planners and providers, and agriculture.] http://www.azwater.gov/azdwr/StatewidePlanning/Conservation2/Residential/documents/Conservation_tips_2015.pdf
3. [This website provides the conservation requirements and management within the AMAs, which includes Agriculture Conservation Program, Municipal Conservation Program, and Industrial Conservation program.] https://new.azwater.gov/ama/ama-conservation
4. [Shows the same website as #2 in this section.] https://new.azwater.gov/conservation

Section 5
PROJECTS AND PRACTICES BETWEEN WILLING PARTIES THAT IMPROVE WATER MANAGEMENT

The following projects and practices can be implemented to provide better water management. Although these projects do not increase Arizona water supplies, they can make water management more effective.
5.1 Water Supply Transfers for CAP and Colorado River Water Users

CAP and Colorado River water users may execute an agreement with willing priority 1, 2, or 3 Colorado River water users to fallow land and voluntarily transfer water, with compensation, to deliver water to areas that are served by the Colorado River or CAP canal (Includes authorities outlined in ARS 48-3715.01). The Secretary of the Interior will consider and may approve the transfer. A person seeking to transfer its rights to Colorado River must first confer and obtain the advice of the Director of ADWR. A.R.S. § 45-107(D). ADWR has issued a substantive policy statement containing criteria the Director will follow to determine whether to recommend a proposed transfer to the Secretary of the Interior. If the new delivery location is within the Cap service area, the parties must reach agreement with the CAWCD and BOR through the System Use Agreement. Transferred water supplies may benefit water users in the following planning areas: Colorado Main Stem North, Colorado Main Stem South, Basin and Range/AMAs. The cost of transferring water supplies depends on the value of Colorado River water at the time of the agreement and the specific terms of the agreement.

Agreements could include the following parties:

1. High Priority Colorado River water rights holders, CAP and USBR.
2. Irrigation Districts or Indian Tribes with Colorado River contracts, CAP water users, AWBA. An Indian Tribe may not transfer its water rights without approval of Congress. Most Indian Tribes that obtained an allocation of CAP water through a Congressionally approved settlement have the right to lease their CAP water within certain areas of the state. Indian Tribes that have a Colorado River water entitlement under the decree in Arizona v. California cannot lease their water off of their reservations because Congress has not yet authorized such leases.
3. The Central Arizona Project and the USBR for wheeling water through the CAP canal.

The following political challenges may be encountered:

1. What starts as a voluntary program may be perceived as something that cannot be reversed once reliance on a temporary water supply is established.
2. Those entities offering the temporary fallowing and water may want assurances that no long-term commitment is implied or expected.
3. Farmers and other interests along the Colorado River have traditionally been vocal opponents to water transfers to the rest of the state.
4. Residents of the agricultural areas from which the fallowing is occurring may fear that their water rights are being given up for the benefit of the larger metropolitan areas.
5. Demonstration of fair market value and direct benefit to the community for the temporary water will be important.
6. Indirect economic impacts to the community from fallowing will be an important consideration.

5.2 Modify Operation of the Roosevelt Dam to use the Flood Control Space

Roosevelt Dam (Figure 15) is operated by SRP. Modified Roosevelt Dam currently has ~556,000 acre feet (AF) of storage designed as Flood Control space that was added as part of the Safety of Dams Act. The current Water Control Manual for the dam states that once water enters flood control space it must be evacuated within 20 days. This project consists of an operational change and merely proposes to extend the timeframe that water can be stored in flood control.
space through the use of the Forecast Informed Reservoir Operations (FIRO) used by SRP. Water temporarily stored in flood control space could then be used for direct delivery and/or recharge for the Basin and Range Planning Areas.

Figure 15  Roosevelt Dam and Reservoir (Photo courtesy of the Salt River Project)

The volume of water that could be beneficially used by using the flood control space is not known. At this time, no hydrologic analysis has been completed to estimate the volume of water that could be utilized by this operational change.

The cost associated with this project would primarily be permitting and any associated mitigation.

Beneficiaries of this project would be SRP shareholders which are primarily cities.

Increasing the duration that water is stored in flood control space may result in environmental impacts due to a longer period of flooding riparian ecosystems along in-flowing rivers and streams. Environmental mitigation with its associated costs would be required.

Operational changes would be required, and changes to US Army Corp of Engineers Water Control Manual for Modified Roosevelt Dam would be required. A modification of SRP’s storage permit for Roosevelt Dam may also be needed. Also, longer term releases might impact at-grade crossings through the Salt River.

5.3 SRP-CAP Interconnect Facility

The SRP-CAP Interconnect Facility (SCIF) is a proposed project to connect SRP’s South Canal with the CAP canal that together with the existing CAP-SRP Interconnect Facility (CSIF) at the
Granite Reef Dam (see Figure 16). This project will allow water to move from the SRP to the CAP water systems. This proposed facility would serve to build further regional water resiliency by increasing the flexibility of existing infrastructure. Water in the New Conservation Space (NCS) in Roosevelt Reservoir can be used off project, so the SCIF would encourage increased use of this water.

Figure 16   Granite Reef Dam with the CAP-SRP Interconnect. (Photo courtesy of the Salt River Project)

Examples of how water resources could be better utilized through the use of the SCIF are as follows:

1. Direct Delivery of Roosevelt Dam NCS water to Mesa, Chandler, and Gilbert's CAP treatment plants for use off-project where it is needed. Currently NCS water can only be delivered through SRP's delivery system.
2. Indirect Delivery of NCS to benefit Peoria, Glendale, Phoenix, and Scottsdale's CAP treatment plants for use off-project where it is needed.

CAP LTSC stored within SRP's boundaries intended to meet off-project demand during a shortage or normal operations could be recovered using SRP's wells and then delivered to CAP customers via exchange. This could facilitate AWBA recovery and allow the recovered water to be delivered to CAP customer's normal point of delivery, such as a city's water treatment plant. Currently recovered LTSCs stored within SRP's boundaries using SRP's wells can only be delivered through SRP's delivery system.

The size of the facility and therefore the cost are not known at this time. However, the cost is expected to be viable for most municipal water users who would pay for use of the facility.

Agreements for the transfer of water would need to be made between SRP, CAP and NCS users.
Section 6

WATER AUGMENTATION CONCEPTS REQUIRING FURTHER DEVELOPMENT

Several potential water augmentation concepts were considered but are not yet developed sufficiently to be recommended as viable water augmentation ideas. Nevertheless they are listed here for additional research and consideration. Common issues among these concepts include:

- Each concept may have the potential to augment water supplies.
- It is not possible to quantify the amount of water supply that could be added.
- It is difficult to delineate and distribute costs associated with each augmentation concept.
- Private stakeholders may not want to contribute funds due to the difficulty in assigning a cost to a corresponding increase in water supply.
- More research is required to establish methods and quantifiable gains.
- Coordination and cooperation of Federal, State, local government entities as well as private stakeholders is required, with potential new divisions of responsibility.

6.1 Weather Modification

Cloud Seeding is a weather modification practice aimed at increasing precipitation in a target region by introducing seeding agents into clouds to enlarge cloud droplets and ice crystals, with the intent to increase precipitation in the form of rainfall or snow. Cloud seeding introduces additional particles or nuclei into the atmosphere, causing more ice crystals to form. As the ice particles grow, they attract nearby water vapor and droplets, growing larger and heavier. These enlarged ice particles eventually fall as snow. Ground based seeding equipment (See Figure 17) is the most common approach to inject silver iodide into the atmosphere. Silver iodide compounds and dry ice are the most common cloud seeding agents.

The cloud seeding is done to enhance the natural formation of precipitation in the atmosphere. As wind pushes moist air over rising terrain, the rising air cools and water droplets are then formed through condensation, resulting in the formation of orographic clouds. The clouds consist of small droplets that, despite below-freezing temperatures, remain liquid. The water’s purity and the lack of foreign particles in the atmosphere prevent the droplets from freezing, forming supercooled clouds. As temperatures decrease further, the droplets form ice crystals around small atmospheric particles such as dust (known as "condensation nuclei").
SRP conducted some of the earliest cloud seeding operations in Arizona. During the 1950s, a time of drought in Arizona, SRP set up a series of ground-based seeders on its 13,000-square-mile watershed. The operations relied on air masses to lift propane-burned silver iodide for seeding. SRP also contracted for aerial seeding during the 1950s and 1960s. These early efforts were suspended when drought conditions eased.
The Wyoming Weather Modification Pilot Program (WWMPP) was conducted by Wyoming Water Development Commission (WWDC) between year 2008 and 2014 in the Medicine Bow and Sierra Madre Ranges. The study showed that the ground based silver Iodide cloud seeding increased precipitation by 3 – 17 percent. The study estimated the cost of this water ranges from $27 - $427 per AF. The study also concluded a negligible impact on the environment. The study concluded that cloud seeding is a viable technology to augment existing water supplies for the Medicine Bow and Sierra Madre Ranges, although additional research and development is needed.

In Arizona, cloud seeding can be conducted with a permit from ADWR according to A.R.S. 45-1601-1607. Permit requirements can be one way to manage cloud seeding to prevent undesirable or unintended consequences. To the extent that cloud seeding is successful, the costs are favorable. Weather modification may have potential to increase water supplies in Arizona, however additional study is needed to implement cloud seeding as a water augmentation option.

References:

1. [In this presentation, the history of cloud seeding in Arizona was explained. This includes Arizona weather modification projects and the relevant research conducted.]
   http://www.winterwatershedconference.org/presentations_2015/History%20of%20Cloud%20Seeding%20in%20AZ%20James%20Walter%20SRP%20Jan%2029%202015.pdf

2. [This presentation provides more background on Arizona's history of cloud seeding and the state's recent advancements and interests on the activity.]
   http://www.cpwac.org/presentationfiles/cloud%20seeding.pdf

3. [This study, the Wyoming Weather Modification Pilot Program (WWMPP), was conducted to analyze the feasibility of implementing winter orographic cloud seeding to increase Wyoming water supplies. Physical, statistical, modeling, and cost analyses were conducted to provide recommendations prior to using this technology.]
   http://wwdc.state.wy.us/weathermod/WYWeatherModPilotProgramExecSummary.html

4. [This article presents the measurements conducted from radars and aircraft-mounted cloud physics probes to help observe the initiation, growth, and fallout to the mountain surface of ice crystals resulting from glaciogenic seeding.]
   https://www.pnas.org/content/115/6/1168

5. [In this article, the results of the Idaho Experiment (SNOWIE) project were presented. Ground-based radars and airborne sensors measurements were conducted to study the impacts of cloud seeding on winter orographic clouds by initially observing physical chain of events following seeding.]
   https://journals.ametsoc.org/doi/full/10.1175/BAMS-D-17-0152.1

6. [This section reviews the background of Arizona's interest in weather modification and how cloud seeding works to attain this goal. It also highlights the mixed responses of the technology.]

7. [Shows up similar to #3 before section 4.3]
6.2 Phreatophyte Management

A phreatophyte is a deep-rooted plant that draws water directly from the groundwater table or from water infiltrating the subsurface from canals, streams, or rivers. Non-native phreatophytes such as salt cedar (Tamarisk) and Arundo (elephant grass) grow along the Colorado River, Gila River, and its tributaries (See Figure 18). These plants use large volumes of water and therefore reduce groundwater and streamflows. Phreatophytes also have the potential for encroachment on, as well as environmental effects on carbon cycling and evapotranspiration rates. Active management and control of these plants has the potential to help improve water supplies in several Arizona River Basins (Lower Gila, Gila Bend, Basin and Range AMAs, Upper Gila, Verde, Lower San Pedro, Upper San Pedro).

Management of phreatophytes and other invasive species could include chemical, mechanical/physical, and / or biological controls. The usefulness of each type of control is site-specific and dependent on plant type, physical conditions, and available access. The type of permits required to implement a management plan would be dependent on the type of control method used, and all methods would require maintenance programs. The initial cost of removing woody plants would be small relative to the cost of desalination and other types of water augmentation projects, but the cost/benefit of managing subsequent vegetation regrowth needs to be assessed because phreatophytes would need to be managed in perpetuity.
Although active management of phreatophytes could have a beneficial impact on Arizona water supplies, more research is needed to quantify water supply benefits and assess environmental impacts. The potential negative impact on the Southwestern Willow Fly Catcher (*Empidonax traillii extimus*), an endangered species, or any other protected species affected by phreatophyte management, is one issue that would need to be considered in any management plan.

References:

1. [This article reviewed different studies associated with recharge estimation methods, mechanisms by which woody plants impact groundwater recharge, effects of woody plant on recharge across different soil and geology, hydrological repercussions of woody plant removal.]

2. [This article provides a framework for conceptualizing how woody plant encroachment is likely to affect components of the water cycle within these ecosystems.]
   https://esajournals.onlinelibrary.wiley.com/doi/10.1890/03-0583

3. [This post discusses the reasons why mesquite trees are replacing grasslands by providing findings from relevant research.]
   https://uanews.arizona.edu/story/mesquite-trees-displacing-southwestern-grasslands

4. [In this assessment, the parties of Memorandum of Understanding (MOU) investigates potential water augmentation alternatives that might provide future water supplies within the Colorado River Basin.]
   https://riversedgewest.org/sites/default/files/files/TRO_Assessment_FINAL%2012-09.pdf

6.3 Forest Management

Healthy forests collect rain and snow melt that feed rivers and streams, and ensure an adequate water supply, while unhealthy forests experience catastrophic wildfires, contaminate water supplies and reduce the useful life of reservoirs. Healthy forests also allow more water to reach underground aquifers and streams and rivers (Figure 19).

The dense and over-stocked forests of Arizona are not natural and have created forests that are unhealthy, highly susceptible to insect and disease infestations. Couple unhealthy forests with chronic drought and wildfires burn extremely hot and are more often catastrophic in size and intensity. Such fires leave watersheds vulnerable to flooding and erosion. The post fire floods carry significant loads of ash, sediment and debris downstream that destroy fish habitats and riparian areas and reduce the available storage capacity of downstream reservoirs. The water is also costly for cities to treat to potable water standards.

Arizona forested areas contribute as much as 90 percent of the water that flows into streams and rivers and the Salt and Verde rivers supply about half of the drinking water in the Phoenix metropolitan area. So, Arizona’s forests are critical to the state water supply. Investment in improving the health of Arizona’s forests ensures a healthy and resilient watershed (Figure 20). Implementing large scale restorative treatments across Arizona’s forests are critical to protecting forest ecosystems, rural communities, recreational values, habitat for endangered species and the water supply for a large majority of Arizona residents (Figure 21).
Figure 19  Arizona Forests to be Managed for Improved Water Quantity and Quality

Figure 20  Thinning Forests (Photo Courtesy of the Nature Conservancy)
The link between forest management practices and streamflow's in Arizona have been studied since the mid-1950s with the most notable study being the Beaver Creek Experiment that was conducted from 1955 to 1981. More recent studies have been or are being conducted by entities including SRP and The Nature Conservancy.

Arizona's 2015 Forest Action Plan Identified "Improving water quality and quantity from forested watersheds" as a critical issue and set a goal to collaboratively protect and enhance water quality and quantity of forested watersheds. Large scale multi-agency funded forest management projects are presently planned for Arizona with the largest project being the Four Forest Restoration Initiative that will employ forest management practices (including mechanical thinning and controlled burns) to sections of a 2.4 million-acre span on the Apache-Seagraves, Coconino, Kaibab and Tonto National Forest.

Large scale forest management efforts, such as forest thinning and controlled burns, will potentially contribute to water augmentation efforts for Arizona by increasing water runoff and river flows, as well as providing other positive benefits such as improving water balance and resilience, and reducing evapotranspiration losses. These efforts also reduce the risk of uncontrolled fires, subsequently reducing the negative impacts of flooding, which results in water runoff entering streams and rivers in more controlled flows that can be utilized to augment water supplies.

However, more research is needed to quantify the influence of large-scale mechanical thinning efforts on runoff and to determine how long the positive benefits will last. The positive effects of forest thinning activities may be short-lived due to understory vegetation regrowth. Additional forest management methods, such as prescribed burns, will be needed to extend the duration of the positive effects.
References:

1. [The website describes what the Four Forest Restoration Initiative (4FRI) is and the program's vision, which includes forest ecosystems restoration to sustain thriving forest communities.]
   https://4fri.org/

2. [This study was conducted by utilizing and modifying a historical runoff model to construct scenarios that estimate increases in runoff from thinning ponderosa pine at the landscape and watershed scales based on a variety of important variables, which include pace, extent and intensity of forest treatments and variability in winter precipitation. It aims to understand how management practices can improve forest resilience under unexpected scales of drought and wildfire.]
   https://journals.plos.org/plosone/article?id=10.1371/journal.pone.0111092

3. [In this article, the changes in flow, climate, and forest conditions in the Salt River in central Arizona from 1914 to 2012 were analyzed to compare and evaluate the effects of changing forest conditions and temperatures on flows.]
   https://journals.plos.org/plosone/article?id=10.1371/journal.pone.0187875

4. [The report discusses the Arizona Forest Action Plan, a strategic plan to target forest-related conditions, trends, threats, and opportunities]

5. [The website provides Forestry Best Management Practices for landowners and professionals.]
   https://mylandplan.org/content/forestry-best-management-practices-0

6. [This post highlights the importance of Arizona's forests to the ecosystems and water supplies, discusses the need for forest treatment and restoration, and presents current actions to aim for the goal.]
   https://wrrc.arizona.edu/water-resources-rrprotection-spurs-rrrestoration-actions

7. [This post discusses the effects of ecosystem management practices (restoration treatments) on hydrologic systems, including streams, springs, and groundwater.]
   https://wrrc.arizona.edu/ecoRRydrology-forest-rrestoration

8. [This report explains the actions needed to restore and maintain healthy forests, what wildfires and healthy forests are, the impacts of wildfire on water quality, treatment and restoration, and ongoing actions in Arizona.]
   https://arizonaforward.org/resources/Pictures/FINAL.HFE.PRIMER.pdf

9. [This website describes the four national forests — Kaibab, Coconino, Apache-Sitgreaves, and Tonto — involved in collaborative landscape-scale restoration efforts.]
   https://www.fs.usda.gov/main/4fri/home

10. [This section describes the difficulties experienced during the restoration of the Chesapeake Bay to reduce phosphorus and nitrogen entering the area.]
    https://www.nap.edu/read/6020/chapter/3#29
Section 7

IMPEDEMENTS TO WATER AUGMENTATION

Several issues were identified in the evaluation process that represent legal, policy, and institutional constraints to implementing water augmentation projects. As described below, resolving these issues paves the way for expanded opportunities for local water supply augmentation.

7.1 Little Colorado River and Gila River Water Rights Adjudications

Two ongoing water rights adjudications in state courts will resolve claims to appropriable water in much of the state. The stream adjudications, which started in the 1970s, aim to quantify water rights and establish priorities within the Gila and Lower Colorado River basins, which cover most of the state (Figure 22). The watershed of the Gila and its tributaries - the Salt, Verde, Agua Fria, Santa Cruz, and San Pedro Rivers - cover most of the state's population and agriculture. The Gila River Adjudication, which is in the Maricopa County Superior Court, involves more than 32,000 claimants and 57,000 claims. The Little Colorado River Adjudication, which is in the Apache County Superior Court, involves more than 5,000 claimants and 30,000 claims. The adjudications will comprehensively settle all water rights claims on the river systems, a complex task that began more than 40 years ago and may take many more decades to resolve. An added complication was introduced by the Arizona Supreme Court in 2000 by defining subflow as "saturated floodplain Holocene alluvium," essentially underground water in sediments associated with the river. Under previous Arizona Supreme Court rulings, subflow is treated as appropriable surface water under the law, the rights to which must be quantified in the adjudication. In practice, this means well owners near a river may need a surface water right to pump from their wells, which requires quantification in the ongoing stream adjudication.

Since the 1970s, development has increased reliance on this water, the combined claims to which exceed the available supply. Eventual resolution of the claims in court means some current water users may no longer be able to use this water. This uncertainty presents a significant barrier to planning for future water needs and long-term reliability and prevents water users from assessing water augmentation needs. These claims also include environmental and other interests seeking water for instream flows, the needs of which can be difficult to evaluate without adjudicated water rights.
Figure 22  Map of Arizona Stream Adjudications

Legend

- Gila River Adjudication Area
- Little Colorado Adjudication Area
- Water Resource Planning Areas

Data Sources:
- Planning Areas, Groundwater Basin: ADWR
- Planning Areas Affected by Water Right Claims: Kyl Center for Water Policy at Morrison Institute
- Rivers, River Basin, Street Map, State Boundaries: ESRI

Last Revised: July 30, 2019 M:\Client\ADWR\10218\GIS\mxd\Deliverables\Draft Report\Figure 21 Map of Arizona Stream Adjudications.mxd
7.2 Unresolved Indian Water Rights Claims

Unresolved Indian Water Rights Claims is a subset of the Little Colorado River and Gila River Water Rights Adjudications. There are 22 federally recognized tribes in Arizona with reservation land that covers nearly 28 percent of the state. Figure 23 shows the status of tribal water settlements throughout Arizona. Summaries of settled tribal water claims and outstanding claims are provided in Table 6 and Table 7, respectively. Two important Supreme Court Cases conceptually identified the water rights of tribal entities in Arizona. The 1908 case *Winters v. United States* set the date of water rights as the date when the reservation was established. The 1963 case *Arizona v. California* established the practicably irrigable acreage standard for quantifying tribal water rights. The 1963 case adjudicated the federally reserved water rights of four tribes with land adjoining the Colorado River providing "perfected" rights to Colorado River water. In 2001, the Arizona Supreme Court rejected the "practicably irrigable acreage" standard as the exclusive standard for quantifying federal reserved water rights for Indian reservations. Instead, the court held that an Indian reservation should be allocated the quantity of water necessary to achieve its purpose as a permanent homeland for the Indian tribe, which may include water for multiple present and future uses. *In re General Adjudication of All Rights to Use Water in Gila River System and Source*, 35 P.3d 68 (Ariz. 2001) (*Gila V*). Seven other tribes have obtained congressional settlements, many of which provided the tribes with CAP subcontracts for a combination of high priority Indian water and in some cases, lower priority Non-Indian Agriculture (NIA) water. Some settlements also include groundwater pumping allotments and protections from neighboring groundwater pumping, rights to reclaimed water, and surface water rights to water from the Gila, Salt, and Verde Rivers. Another three tribes have partial settlements, and eight have still unresolved claims.

In 2004, the Arizona Water Settlements Act reserved 46 percent of CAP's long-term subcontracts (650,724 AF) for tribes and reallocated 67,300 AF of CAP NIA priority water for the settlement of tribal water claims in the future. This reallocation of future claims reserves 6,411 AF for a settlement for the Navajo Nation in the future and the remaining 60,889 AF of NIA water has yet to be allocated to tribes.

The settlement of unresolved tribal water rights claims is important not only from the perspective of justice for Native communities, but also in terms of assessing statewide water availability. Tribal interests cannot fully participate in water augmentation planning across the state until their claims are resolved. The settlement of all claims will result in allocation of water supplies that are reserved for settlements, allowing tribes to assess their complete water supply portfolio and consider participation in augmentation projects. Similarly, in the absence of settlement, many Arizona communities remain uncertain as to the full scope of their water supply, since early priority tribal rights remain unresolved.
### Table 6  Summary of Arizona Tribal Water Settlements or Decreed Water Rights

<table>
<thead>
<tr>
<th>Tribe</th>
<th>Water Rights Status(1)</th>
<th>Statute(2)</th>
<th>Total Settlement Amount (AFY)</th>
<th>Source of Water</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ak-Chin Indian Community(5,11)</td>
<td>Settled</td>
<td>Ak-Chin Indian Water Rights Settlement Act of 1978 (amended 1984, 1992, 2000)</td>
<td>72,000 (shortage) 75,000 (normal) 85,000 (surplus)</td>
<td>CAP, Colorado River Priority 3</td>
</tr>
<tr>
<td>Cocopah Tribe(4)</td>
<td>Decreed</td>
<td>Arizona v. California (1963)</td>
<td>10,847</td>
<td>Colorado River</td>
</tr>
<tr>
<td>Colorado River Indian Tribes(5)</td>
<td>Decreed</td>
<td>Arizona v. California (1963)</td>
<td>662,402</td>
<td>Colorado River</td>
</tr>
<tr>
<td>Fort McDowell Yavapai Nation(5)</td>
<td>Settled</td>
<td>Fort McDowell Indian Community Water Rights Settlement Act of 1990</td>
<td>36,350</td>
<td>CAP, Verde River, SRP, Roosevelt WCD</td>
</tr>
<tr>
<td>Fort Mojave Indian Tribe(5)</td>
<td>Decreed</td>
<td>Arizona v. California (1963)</td>
<td>103,535</td>
<td>Colorado River</td>
</tr>
<tr>
<td>Fort Yuma Quechan Indian Tribe(5)</td>
<td>Decreed</td>
<td>Arizona v. California (1963)</td>
<td>6,350</td>
<td>Colorado River</td>
</tr>
<tr>
<td>White Mountain Apache Tribe(7)</td>
<td>Settled</td>
<td>White Mountain Apache Tribe Water Rights Quantification Act of 2010</td>
<td>99,000</td>
<td>CAP, Salt River</td>
</tr>
<tr>
<td>Yavapai-Prescott Indian Tribe(8)</td>
<td>Settled</td>
<td>Yavapai-Prescott Indian Tribe Water Rights Settlement Act of 1994</td>
<td>1,550</td>
<td>City of Prescott, Granite Creek</td>
</tr>
<tr>
<td>Pueblo of Zuñi(9)</td>
<td>Settled</td>
<td>Zuñi Indian Tribe Water Rights Settlement Act of 2003</td>
<td>7,000</td>
<td>Little Colorado River, Groundwater</td>
</tr>
<tr>
<td>Hualapai Tribe(10)</td>
<td>Partially settled</td>
<td>Bill Williams River Water Rights Settlement Act of 2014</td>
<td>N/A</td>
<td>Colorado River</td>
</tr>
</tbody>
</table>

Notes:


(8) Although Congress approved the settlement, the settlement will not become effective until the Secretary of the Interior issues a Record of Decision approving the construction of the White Mountain Apache Tribe rural water system in a configuration substantially similar to that described in the federal legislation approving the settlement.


### Table 7  Summary of Outstanding Arizona Tribal Water Claims

<table>
<thead>
<tr>
<th>Tribe</th>
<th>Status of Negotiations(^{(1,2)})</th>
</tr>
</thead>
</table>
| Havasupai Tribe | • Claims to Colorado River, and groundwater and surface water still unresolved  
| | • Federal negotiation and assessment team in place  
| | • Settlement discussions in early stages |
| Hopi Tribe | • Claims to the Colorado River, Little Colorado River, and groundwater and surface water still unresolved  
| | • Federal negotiation and assessment team in place  
| | • Settlement previously under negotiation but no current negotiation. A joint settlement by the Hopi Tribe and Navajo Nation regarding Little Colorado River water rights was proposed in 2012, but an agreement was not reached. |
| Hualapai Tribe | • Settlement of claims in Bill Williams watershed created a development fund which the tribe could use to acquire Colorado River water rights (the tribe has yet to do so).  
| | • Additional claims proposed to be settled with 4,000 AFY of CAP NIA water and funding for construction of pipeline to deliver water from Colorado River to the reservation  
| | • Legislation introduced to Congress in May 2019 (S. 1277; H.R. 2459) |
| Kaibab Band of Paiute Indians | • Water rights are unquantified  
| | • Settlement discussions in early stages |
| Navajo Nation | • 6,411 AFY of CAP NIA water is reserved for future settlement with the Navajo Nation pursuant to the Arizona Water Settlements Act  
| | • Claims to Colorado River and Little Colorado River still unresolved  
| | • Federal negotiation and assessment team in place  
| | • Settlement previously under negotiation but no current negotiation. A joint settlement by the Hopi Tribe and Navajo Nation regarding Little Colorado River water rights was proposed in 2012, but an agreement was not reached. |
| Pascua Yaqui Tribe | • Water rights are unquantified |
| San Carlos Apache Tribe (Gila River claims) | • Partial settlement provided rights to the Salt River  
| | • Additional claims to Gila River still unresolved  
| | • Federal negotiation and assessment team in place for San Carlos Apache and Gila River Indian Community to address Gila River claims |
| San Juan Southern Paiute Tribe | • Claims to Little Colorado River, and groundwater and surface water are unresolved  
| | • Negotiations have not included the San Juan Southern Paiute Tribe |
| Tohono O'odham Nation (Sif Oidak District) | • Partial settlement provided rights to CAP water for San Xavier and Schuk Toak Districts  
| | • Additional claims for remaining districts, including the Sif Oidak District, still unresolved  
| | • Federal negotiation and assessment team in place  
| | • Settlement discussions in early stages |
| Tonto Apache Tribe | • Water rights are unquantified Federal negotiation and assessment team in place  
| | • Settlement discussions ongoing for several years |
| Yavapai Apache Nation | • Claims to Verde River and groundwater still unresolved  
| | • Federal negotiation and assessment team in place  
| | • Settlement discussions ongoing for several years |

Notes:


The settlement of tribal water claims also provides the potential for collaborative augmentation options as permitted by the terms of the settlement. Some tribal entities currently lease a portion of their water allocations off reservation to non-Indian users, but under the terms of the Tribal CAP contracts, until a tribe with a CAP allocation has a settlement, they remain unable to lease but may be able to store their CAP allocation off of the reservation. The amount of CAP water legally available for lease and the locations where it can be used are listed in Table 8. Unleased water represents water that could be available for off-reservation uses. The settlement of additional claims and tribal allocation of the additional CAP water could potentially result in more water available for leasing.

Table 8  Arizona Tribal Settlements with Leasing Allowances for CAP Water

<table>
<thead>
<tr>
<th>Tribe</th>
<th>CAP Entitlement Potentially Available for Lease (AFY)</th>
<th>Areas Permitted by Settlement to Use Leased CAP Water</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ak-Chin Indian Community</td>
<td>72,000 to 85,000</td>
<td>Phoenix, Pinal, or Tucson AMAs</td>
</tr>
<tr>
<td>Fort McDowell Yavapai Nation</td>
<td>18,233</td>
<td>CAP Service Area (Pima, Pinal, and Maricopa Counties)</td>
</tr>
<tr>
<td>Gila River Indian Community</td>
<td>311,800</td>
<td>Within Arizona</td>
</tr>
<tr>
<td>San Carlos Apache Tribe (Salt River claims only)</td>
<td>64,135</td>
<td>Pima, Pinal, Maricopa, Yavapai, Graham, and Greenlee Counties</td>
</tr>
<tr>
<td>Salt River Pima-Maricopa Indian Community</td>
<td>13,300</td>
<td>CAP Service Area (Pima, Pinal, and Maricopa Counties)</td>
</tr>
<tr>
<td>Tohono O’odham Nation</td>
<td>66,000</td>
<td>CAP Service Area (Pima, Pinal, and Maricopa Counties)</td>
</tr>
<tr>
<td>White Mountain Apache Tribe</td>
<td>25,000</td>
<td>Maricopa, Pinal, Pima, and Yavapai Counties</td>
</tr>
</tbody>
</table>

Notes:

7.3 Groundwater Management Planning

The Groundwater Management Act of 1980 created AMAs which brought groundwater regulation to the state’s most populated areas that were experiencing groundwater overdraft. Outside of these AMAs, shown on Figure 24, groundwater use is essentially unrestricted, and local water resources are not quantified or protected. Groundwater management needs in rural Arizona are unique to each area, so the groundwater management practices in urban areas is not likely to fit rural areas. Some areas are experiencing overdraft, and other rural areas of the state are not experiencing overdraft or population growth. Furthermore, the completion of the stream adjudications and the resolution of outstanding tribal claims will have a great impact on several of these rural areas. These processes will greatly determine who will be permitted to continue pumping water and how much. In rural areas of the state, there are few options for augmentation and it may be difficult to offset the impact of water withdrawal regulation. Due to the wide variation in groundwater supply, water demand characteristics, and adjudication status, local solutions with local control may be the most effective way to implement groundwater management.
LONG-TERM WATER AUGMENTATION OPTIONS FOR ARIZONA | WATER AUGMENTATION STUDY

Figure 23 Map of Basin Fill Aquifers and Planning Areas in Arizona

Legend

Active Management Area (AMA)
Basin Fill Aquifers
Water Resource Planning Areas

Data Sources:
Planning Areas, AMAs: ADWR
Rivers, River Basin, Street Map, State Boundaries: ESRI

Figure 24 Map of Basin Fill Aquifers and Planning Areas in Arizona

Last Revised: July 30, 2019 M:\Client\ADWR\11028a.00\GIS\mxd\Deliverables\Draft Report\Figure 23 Map of Basin Fill Aquifers and Planning Areas in Arizona.mxd
The extent of basin-fill aquifers on Figure 24 show that the portions of the state with significant groundwater resources extend beyond the AMAs. These areas, especially in the Big Chino at the headwaters of the Verde River, as well as the southern and western portions of the state, could benefit from groundwater management planning.

A groundwater management planning process involves quantifying groundwater resources, assessing the rate at which supplies are being depleted, setting goals for long-term reliability, and implementing sustainable practices and monitoring results. Evaluating augmentation needs and options are part of the overall planning process.

Groundwater management planning typically includes the following components:

- Delineation of basin management areas based on hydrologic or political boundaries
- Management objectives, in the form of goals for water use and sustainability of supplies based on the values of the management area
- An inventory of available water supply and demand to determine if groundwater depletion is occurring
- Potential management actions and augmentation projects, and a process for evaluating and implementing these concepts
- Water conservation components
- Monitoring, reporting, and management protocols to measure progress and prompt course corrections
- Outreach and education to basin residents

Other states have implemented programs to incentivize voluntary regional groundwater management and planning. A similar program for rural areas of Arizona would assess water resources and needs, and could be structured to maintain local control. One such program is in the state of Texas' Regional Water Planning program. Local planning groups from each planning area developed plans that evaluated water supplies and future demands and laid out strategies to meet the projected needs. All regional water plans were required to be approved by the state agency, the Texas Water Development Board, which provides funding for planning efforts. The State Water Implementation Fund for Texas (SWIFT) program provides funding to implement projects that are identified in the regional plans.
References:

1. [This report discusses the water rights settlement agreement between the Yavapai-Prescott Indian Tribe, United States of America, the State of Arizona, and City of Prescott, and the Chino Valley Irrigation District.]

2. [This report discusses the resolution of the Zuni Indian Tribe water right settlement agreement in the Little Colorado River basin the Arizona.]

3. [This report presents the amended and restated Gila River Indian community water rights settlement agreement among the United States of America, the State of Arizona the Gila River community, and other parties.]

4. [This appendix of the Arizona Water Atlas discusses different Indian water rights claims, congressionally authorized settlements, and current settlement negotiations.]

5. [This report presents the amended and restated White Mountain Apache Tribe water rights quantification agreement between the tribe, the United States, the State of Arizona, and other parties.]

6. [This presentation identifies the Arizona tribes with: water rights through litigation or settlement, or outstanding water rights claims, and the current status of tribal settlement negotiations in Arizona.]
7. [This website explains the background of stream adjudications required to establish the extent and priority of water rights in the Gila River system and the Little Colorado River system. It also provides further information on those who may be affected, how to file or amend a statement of claimant, etc.]
   California Department of Water Resources. Integrated Regional Water Management. https://water.ca.gov/Programs/Integrated-Regional-Water-Management

8. [This report provides a list of the status of municipal and industrial CAP Indian and Non-Indian subcontracts, and the associated entitlements.]

9. [This article provides an overview of the current information on tribal water rights in the Colorado River Basin and a background of emerging policy discussions aiming to assist tribes to take advantage of the full benefits to their rights through voluntary transfer mechanisms.]

10. [This report explains why it is so difficult to resolve the Gila Adjudication, presents a series of interviews conducted to identify the impacts of the Adjudication on economic development, and provides strategic solutions vital to settling the Adjudication.]

11. [This presentation discusses the background of the Gila River Indian community and water settlement, and the Gila River's Utility Model. It also provides some tribal utility development considerations for future work.]

12. [This website aims to provide information by on tribal water uses across the Colorado River basin and some of the prevalent obstacles experienced by the tribes. This research was conducted with in-person interviews with tribal officials, tribal water rights attorneys, and water managers.]

13. [This website provides a list of enacted and partial settlements as of May 2015.]
Appendix A

PERMITS THAT MAY BE REQUIRED ON WATER AUGMENTATION PROJECTS
### Table A
Permits that may be Required on Water Augmentation Projects

<table>
<thead>
<tr>
<th>Title</th>
<th>Requirement</th>
<th>Agency(ies)</th>
<th>Description</th>
<th>Potential Application to Augmentation Projects</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Clean Air Act</strong></td>
<td>Air Emissions Permit</td>
<td>ADEQ</td>
<td>Some Tribal Agencies and Counties</td>
<td>ADEQ and some Arizona tribes have delegated authority from the EPA to administer air permitting in Arizona, and several counties (e.g., Maricopa, Pima, Yuma) have authority within their jurisdiction. Stationary sources of air emissions, such as power plants, WWTFs, and generators, must obtain a permit for releases of regulated pollutants; the level of permit depends upon the volume and type of emissions as well as the location of the source. Dust from construction sites is typically regulated at the county or local level. Certain types of mobile sources are also regulated, but are likely not relevant to water infrastructure projects.</td>
</tr>
<tr>
<td></td>
<td>Section 2 Compliance Review</td>
<td>ADEQ</td>
<td></td>
<td>Section 208 Plans describe wastewater treatment management requirements for areas designated as having substantial water quality control problems. Certain types of facilities within those areas must be in compliance with those plans. ADEQ conducts 208 Plan compliance reviews of all AZPDES permit applications and renewals (see Section 402), new WWTFs discharging over 3,000 gallons per day (gpd), modifications to existing facilities, projects located outside of the planning/service area of the DPA of the receiving WWTF, and new subdivisions with conventional or alternative on-site treatment systems and flows over 100 gpd. Currently there are eight DPAs in Arizona: Maricopa Association of Governments (MAG), Pima Association of Governments (PAG), Northern Arizona Council of Governments (NACOG), SouthEastern Arizona Governments Organization (SEAGO), Central Arizona Governments (CAG), La Paz County, Mohave County and Yuma County.</td>
</tr>
<tr>
<td><strong>Clean Water Act (formally, Federal Water Pollution Control Act)</strong></td>
<td>Section 401 Water Quality Certification</td>
<td>ADEQ</td>
<td>Some Tribal Agencies</td>
<td>The ADEQ or relevant Tribal Agency must review and certify that surface water quality would not be affected by an activity authorized by a Section 402 or 404 permit (see below).</td>
</tr>
<tr>
<td></td>
<td>Section 402 Arizona Pollutant Discharge Elimination System Permit</td>
<td>ADEQ</td>
<td></td>
<td>ADEQ has delegated authority from the EPA to administer the NPDES program in Arizona, as the AZPDES program. Wastewater or stormwater discharges from point or nonpoint sources to surface water must be permitted under the AZPDES program. The level of permit depends upon the volume and type of discharge. Exception: Section 402 permits for facilities near tribal lands may be issued by EPA as an NPDES permit. See also Section 401.</td>
</tr>
<tr>
<td></td>
<td>Section 404 Dredge and Fill Permit</td>
<td>Corps, EPA</td>
<td></td>
<td>Any project requiring the placement of dredged or fill material in waters of the United States must obtain a permit from the Corps. The level of permit (general, individual) depends upon the volume and type of material placed in jurisdictional waters, as determined by the Corps, and the areal extent of impacted waters. EPA has review responsibility for Individual Permits, which require National Environmental Policy Act (NEPA) evaluation. Due to the federal nexus, compliance with ESA and National Historic Preservation Act (NHPA) is also required. See also Section 401.</td>
</tr>
<tr>
<td><strong>Endangered Species Act</strong></td>
<td>Section 7 Consultation</td>
<td>USFWS</td>
<td></td>
<td>Federal agencies must consult with USFWS if a project with a federal nexus has a potential to affect threatened or endangered species, or critical habitat, within the agency’s jurisdiction.</td>
</tr>
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<td></td>
<td>Section 10 Incidental Take Permit</td>
<td>USFWS</td>
<td></td>
<td>A permit is required when non-federal activities will result in “take” of threatened or endangered animal (not plant) species. An HCP must accompany an application for an incidental take permit. The HCP must demonstrate the adequacy of the proposed mitigation and minimization measures to provide substantial benefits to affected species, that adequate funding for the measures will be provided, and that the applicant will, to the maximum extent practicable, minimize and mitigate the impacts of take of listed animal species.</td>
</tr>
<tr>
<td><strong>Federal Land Management Policy Act,</strong> National Forest Management Act, Multiple Use Sustained Yield Act, Wild &amp; Scenic Rivers Act, National Park Service Organic Act, Wilderness Act</td>
<td>Authorization</td>
<td>USFS, BLM, NPS</td>
<td></td>
<td>Use of federal land must be authorized by the administering land management agency. The project's effects on resources managed by the agency must be evaluated, pursuant to NEPA (see NEPA). The type of authorization (e.g., SUP, ROW, easement) and level of NEPA evaluation depends upon the type and duration of the activity, potential effects to resources, and the agency's regulatory programs. Due to the federal nexus, compliance with ESA and NHPA is also required. Project impacts to designated Wild and Scenic Rivers, whether on public or private land, must be reviewed and authorized by NPS.</td>
</tr>
<tr>
<td>Title</td>
<td>Requirement</td>
<td>Agency(ies)</td>
<td>Description</td>
<td>Potential Application to Augmentation Projects</td>
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<tr>
<td>Arizona Water Law (e.g., Groundwater Management Act, Underground Water Storage and Replenishment Act, others)</td>
<td>Permit</td>
<td>ADWR</td>
<td>A WS permit allows the holder to store water obtained from outside an AMA at a permitted underground storage facility within an AMA. In order to store water, the applicant must provide to the ADWR evidence of its legal right to the source water proposed for recharge.</td>
<td>Any project in an AMA that will store water in a GSF, MUSF, or CUSF.</td>
</tr>
<tr>
<td>Groundwater Protection Act</td>
<td>Aquifer Protection Permit</td>
<td>ADEQ</td>
<td>Facilities with a potential to discharge pollutants to an aquifer must be permitted. The level of permit depends upon the type of facility and the volume and type of potential discharges.</td>
<td>Any infrastructure project with facilities (e.g., basins, biosolids land application sites) potentially discharging pollutants to aquifers.</td>
</tr>
<tr>
<td>National Environmental Policy Act</td>
<td>Evaluation</td>
<td>Federal Agencies</td>
<td>Executive federal agencies with discretionary decision-making authority are required to evaluate the potential environmental effects of projects that they conduct, fund, authorize, or permit—the “federal nexus.” The level of evaluation depends upon the extent of potential environmental effect. Some activities are designated by the agency as “categorically excluded” from NEPA evaluation. An Environmental Assessment describes a project that would not result in significant impacts to environmental resources. An Environmental Impact Statement describes a project that would result in significant impacts. Unless categorically excluded or determined to have no significant impacts, an Environmental Impact Statement must be prepared.</td>
<td>Any water project with a federal nexus.</td>
</tr>
<tr>
<td>National Historic Preservation Act, Native American Graves Protection and Repatriation Act, Archaeological Resources Protection Act, Arizona cultural resources regulations and Cultural Resources Management program</td>
<td>Section 106 Consultation; notification, review, and approval</td>
<td>Federal Agencies, SHPO, Native American Tribes, ASLD</td>
<td>Federal agencies must review projects for potential effects to cultural resources (prehistoric or historic sites, traditional cultural properties) and consult with the State Historic Preservation Office and Native American Tribes to mitigate potential effects. Burials on public, tribal, or private lands must be addressed in accordance with federal and state requirements, in consultation with tribes and SHPO. Additionally, ASLD reviews projects on State Trust Lands for compliance with the CRM program.</td>
<td>Any infrastructure project with a federal nexus; any infrastructure project on tribal or State Trust Lands; any project that disturbs a Native American burial site.</td>
</tr>
<tr>
<td>National Reclamation Act of 1902</td>
<td>Authorization</td>
<td>Salt River Project Agricultural Improvement and Power District</td>
<td>The SRP Land Department reviews plans for new electric service or proposed improvements and compatibility with existing SRP facilities and land rights. Land Department also reviews plans for distributed generating facility interconnections to SRP grid.</td>
<td>Any infrastructure project affecting or using SRP power facilities.</td>
</tr>
<tr>
<td>Rivers and Harbors Act</td>
<td>Section 10 Structure Permit</td>
<td>Corps</td>
<td>Corps authorization is required for construction of any structure or in or over any navigable-in-fact (as distinguished from traditionally navigable) water. May require NEPA evaluation (see NEPA). Flood control and related structures constructed by the Corps cannot be altered without Corps approval. May require NEPA evaluation, depending upon extent of modification (see NEPA).</td>
<td>Any infrastructure project crossing a navigable water, such as the Colorado River.</td>
</tr>
<tr>
<td>Safe Drinking Water Act</td>
<td>Underground Injection Control Permit</td>
<td>EPA</td>
<td>Any well injecting certain liquids into the ground requires a UIC permit.</td>
<td>Any project that injects regulated liquids (including brine and brackish water) underground.</td>
</tr>
<tr>
<td>State Enabling Act (and Arizona State Land Code)</td>
<td>Authorization</td>
<td>ASLD</td>
<td>Any entity that uses State Trust Land must apply for approval of that use via several different authorization options: NOI, SUP, ROW. Alternatively, entities may purchase State Trust Land through an auction process.</td>
<td>Any infrastructure project on State Trust Lands.</td>
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</tbody>
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