A Framework for Indirect Potable Reuse in Arizona

Ling-Yee Huang
Masters of Science in Water, Society, and Policy
University of Arizona School of Natural Resources

May 29, 2015

Executive Summary **2**

Introduction **7**

An Overview of Indirect Potable Reuse **7**
1. What is Indirect Potable Reuse? 7
2. What Drives Indirect Potable Reuse? 9
3. Potable Reuse around the World 9
4. Benefits of Indirect Potable Reuse 10
5. Concerns about Indirect Potable Reuse 11

The Federal Landscape for Indirect Potable Reuse **12**
1. Safe Drinking Water Act 12
2. Source Water Assessment Program 13
3. Clean Water Act 14
4. Reconciling the Safe Drinking Water Act and the Clean Water Act 15

State Considerations for Indirect Potable Reuse **16**

Potable Reuse around the United States **17**
1. California 17
2. Texas 18
3. Florida 19

An Overview of Indirect Potable Reuse in Arizona **19**
1. Effluent in Arizona 19
2. Blue Ribbon Panel on Water Sustainability 21

Impediments to Indirect Potable Reuse in Arizona **22**
1. Institutional Overlap 22
2. Legal and Regulatory Impediments 23
3. Overarching Obstacles to Implementing Indirect Potable Reuse 27

Recommendations for an Indirect Potable Reuse Framework in Arizona **29**
1. Requisite Factors for Indirect Potable Reuse 29
2. Recommendations 29

Conclusion **33**

Acknowledgments **35**

References **36**
1. Legal References 36
2. Literature References 36

Appendix A: List of Interviewees **40**

Appendix B: Interview Questions **41**

Executive Summary

Arizona and the southwestern United States sit at the intersection of countervailing forces: relatively rapid population and economic growth but limited water resources and drought conditions that are exacerbated by climate change. Water managers and providers are increasingly interested in indirect potable reuse (IPR) to augment the potable water supply. This white paper provides a broad context of IPR, including its benefits, potential risks, and a snapshot of IPR use in the United States (California, Florida, and Texas) and around the world. It describes the legal and regulatory landscape for IPR, focusing primarily on the Safe Drinking Water Act at the federal level and specific considerations for implementing IPR at the state level. This white paper details the history, context, and status of IPR in Arizona, exploring many of the legal, institutional, technical, and other obstacles to implementing IPR systems. This white paper concludes with recommendations for developing a legal and regulatory framework for implementing IPR in Arizona.

IPR accelerates the natural hydrologic cycle. It returns advanced treated wastewater to the drinking water supply, after an intermediary period where the treated wastewater has passed through an environmental barrier such as a surface water body, a wetland, the unsaturated zone, or an aquifer. IPR can be de facto or intentional, and the type and role of the environmental barrier varies. Unintentional, de facto IPR has occurred for decades where downstream communities withdraw surface water into which upstream wastewater treatment plants (WWTPs) discharge treated wastewater. In the southwestern United States, any diversion from the Colorado River below Lake Mead—including water delivered to the cities of Phoenix and Tucson—contains treated wastewater from Las Vegas, Nevada.

Water managers and water providers in Arizona are now contemplating intentional IPR. In 2010 Arizona Blue Ribbon Panel on Water Sustainability (BRP) identified IPR as a strategy to augment the drinking water supply, focusing on *intentional* reuse in systems where the recharge of treated wastewater is *closely coupled* with the recovery of treated wastewater for potable use. The traditional method of intentional IPR allows treated wastewater to undergo additional soil-aquifer-treatment (SAT) as the water passes through the unsaturated soil layer. As proposed by the BRP, intentional and closely coupled IPR deliberately bypasses the traditional method in favor of directly injecting it into the aquifer.

IPR has many benefits. As a water supply, it is consistent over time and drought-proof. IPR can help mitigate groundwater overdraft and saltwater intrusion. It also maximizes the return on a community's investment in water infrastructure and minimizes the need for additional infrastructure. IPR, particularly closely coupled systems, takes advantage of the aquifer as a storage reservoir. IPR via direct injection into an aquifer is arguably better suited for rapidly urbanizing areas where the cost of land to recharge an equivalent volume of water through recharge basins is prohibitive. IPR thus expands the options for groundwater recharge in areas where the geology is not well suited for SAT or other widely used recharge processes.

However, IPR also raises serious and significant concerns. One of the foremost concerns of IPR is water quality. Simply put, the source water of IPR is wastewater, which potentially contains contaminants not found in or at higher concentrations than in traditional water sources. Regulators, water professionals, and the public are concerned about the potential human health risks of consuming treated wastewater. Although no long-term health impacts from de facto potable reuse have been reporting, research into potential impacts is also lacking.

Another vexing impediment is the fragmented nature of water laws and regulations, which is further complicated by the lack of federal leadership for potable reuse. IPR blends the water cycle with wastewater, reclaimed water, and drinking water into a single system, raising many issues for water resources laws and regulations, management, planning, engineering design, operations, maintenance, and oversight. Thus, the existing legal and regulatory overlay is complex. Federal and state water laws serve different purposes and are administered by different agencies; they vary depending on water quality, water quantity, the use of the water, and the source of the water, among other facets. In Arizona, recharged water must meet state-based Aquifer Water Quality Standards, while recovered water must meet drinking water standards in the federal Safe Drinking Water Act. Federal leadership is important because the U.S. Environmental Protection Agency brings vast resources, established credibility, and scientific and technical information to support efforts to implement IPR.

Less tangible impediments include a hostile rulemaking environment for Arizona agencies and the institutional inertia supporting traditional wastewater treatment and disposal. Implementing IPR and changing the mentality of both regulators and the public about wastewater and its potential uses will require a significant investment of both money and time. The budgets of state agencies in Arizona have been reduced, sometimes drastically, over the past few years. Reduced resources and staff, despite the same or increased workload, means there is lackluster support for new programs. Gaining public acceptance and support for IPR are also critical.

Despite these impediments, Arizona already has important elements of the legal foundation to facilitate closely coupled IPR. One of the most important elements is the legal right to use treated wastewater. In Arizona Public Services Co. v. Long (1989), the Arizona Supreme Court ruled that effluent is a distinct source of water that a city or other entity that produces treated wastewater can use that wastewater as it sees fit. The court concluded that, for allocation purposes, effluent remains a distinct source of water until it is returned to the environment, after which it may be appropriated according to state surface water or groundwater laws.

Two overarching design principles should guide the development of a statewide IPR framework for Arizona. First, any laws or regulations must accommodate individual, case-by-case factors for an IPR system, including the water quality, hydrogeological characteristics, and other characteristics of the aquifer. For example, research and experience have shown that the recharged water quality needs to closely match the receiving groundwater quality, otherwise treatment costs and clogged injection wells become problematic. One potential solution is to rely more on performance standards rather than technology standards. An IPR system would have to meet specific water quality standards, regardless of where it is location, rather than using a specific technology.

Second, IPR rules and regulations should also be forward-thinking and potentially create a path to direct potable reuse (DPR). In contrast to IPR, DPR eliminates the environmental barrier and discharges the treated wastewater directly into the drinking water system. Designing rules and regulations with the flexibility to transition into DPR would reduce the need for revisiting regulations, if and when DPR becomes a viable and palatable option.

The table below summarizes specific and key elements of a legal and regulatory framework for IPR in Arizona and provides recommendations for state action, as identified in this white paper.

Element of IPR		Recommendation for State Action
Definition of IPR	IPR is a broad term that encompasses de facto and intentional reuse and a range of processes. A uniform definition of IPR would help state agencies begin the process of rulemaking to facilitate IPR implementation.	➢ Define IPR, paying particular attention to intentionality and system design. ➢ Adopt a uniform, statewide definition through agency rulemaking. ➢ Incorporate flexibility in the definition that facilitates direct potable reuse in the future.
Water Quality Standards	The source water for IPR is wastewater, which contains higher concentrations of contaminants than traditional raw water sources. Different water quality standards, targeted for different purposes, apply at different points in the IPR treatment process.	➢ Expand the Source Water Assessment Program to include treated wastewater as a potable water source. ➢ Ensure pretreatment programs are in place for all wastewater treatment plants (WWTPs) that receive industrial discharges. ➢ Set uniform standards for the water quality of treated wastewater used for recharge. ➢ Set state Aquifer Water Quality Standards (AWQS) to meet federal Safe Drinking Water Act primary drinking water standards, and treat all wastewater to drinking water standards. ➢ Require IPR systems to demonstrate the technological capacity to consistently and reliably produce treated wastewater that meets the applicable standards.
Relationship to Existing Laws and Regulations	IPR implicates existing laws and regulations, such as those addressing reclaimed water and minimum design criteria for a public water system.	➢ Expand the uses of reclaimed water to include potable reuse or adding another class of water for potable reuse. ➢ Amend the statutory list of beneficial uses to include potable reuse. ➢ Explain clearly through agency guidance or other method how the rule on minimum design criteria affects construction of an IPR system. ➢ Consider how recharged water is classified pursuant to Arizona Public Services Co. v. Long ➢ Consider whether recovered water for IPR fits under existing regulations for Groundwater Under the Direct Influence of Surface Water.

Environmental Barrier	For closely coupled IPR, the environmental barrier is the aquifer. The treated wastewater does not receive additional soil-aquifer-treatment. IPR essentially relies on technology to accelerate the environmental treatment processes of the water cycle.	➢ Address the role of the aquifer as the environmental barrier, including the residence time for treated wastewater, how to determine the residence time, and any minimum distance between the recharge and recovery wells.
Biologically Active Aquifers	Wastewater is more likely to contain pathogens of concern, namely *Giardia lamblia* and *Cryptosporidium*. Both are resistant to standard disinfection techniques, and state AWQS do not address these pathogens. Injected inadequately treated wastewater risks making an aquifer biologically active.	➢ Consider California's approach of requiring 10- to 12-log reductions of viruses, *Giardia lamblia*, and *Cryptosporidium* through a combination of treatment processes and residence time in an aquifer.
Disinfection Byproducts	Chlorine is often added to disinfect water, but it may react with constituents in the water to form disinfection byproducts.	➢ Require a minimal amount of chlorine necessary for disinfection, reduce the age of the treated wastewater, or reduce the total amount of organic compounds in the source water.
Interference with Existing Uses	Much of the existing treated wastewater in Arizona is delivered by contract or other legal obligations to an array of existing users that have invested significant amounts of money to acquire treated wastewater.	➢ Negotiate with existing users for their treated wastewater. ➢ Allocate all new volumes of treated wastewater (from population growth, for example), to potable reuse.
Monitoring and Reporting	Although monitoring and reporting are routine requirements for WWTPs and drinking water treatment plants, IPR requires stringent and real-time monitoring because of the nature of the source water.	➢ Require monitoring as close as possible to real-time. ➢ Streamline monitoring and reporting requirements across different permits and agencies. ➢ Streamline the points-of-compliance where possible. ➢ Establish a centralized database to house monitoring data.

Operator Certification	IPR requires an operator who is knowledgeable in both wastewater and drinking water operations. State-recognized and approved training and certification programs are important to assure state regulators and build public confidence that an IPR system meets specified requirements.	➢ Identify the basic training and certification requirements for IPR operators.
Engineering Report	An Engineering Report describes the IPR system prior to construction and operation. It would notify all agencies involved in the approval, permitting, and construction process for an IPR system and would compel the operator to thoroughly plan and prepare for the system.	➢ Require an Engineering Report that covers the entire IPR system. ➢ Include contingency plans and emergency responses in the report.
Public Participation	Public acceptance of and support for IPR systems are critical. Although IPR may be crisis-driven in some cases, state agencies and IPR operators should work together to build credibility for IPR and public confidence.	➢ Invite public participation when developing an IPR framework. ➢ Develop outreach and public education programs about all aspects of IPR. ➢ Promote transparency and public access to information. ➢ Conduct long-term studies on the health impact of consuming treated wastewater.
Data	Information and data on various aspects of IPR, including de facto reuse over the long-term, potential human health impacts, and benefits of treatment processes, are important in helping state regulators better understand IPR and in building public confidence in IPR.	➢ Conduct research or support universities to conduct research on the long-term health impacts of consuming treated wastewater. ➢ Support research on the ancillary benefits of treatment processes for attenuating non-targeted contaminants.

Five years after the Blue Ribbon Panel report, Arizona has the capacity to develop a robust and practical framework for IPR. The gap between water demand and water supply across the state has motivated innovative and pioneering water management strategies, and IPR represents the next iteration of these strategies to augment the potable water supply.

Introduction

Arizona and the southwestern United States sit at the intersection of countervailing forces: relatively rapid population and economic growth but limited water resources and near-term and potentially long-term drought, exacerbated by climate change. Water has always shaped the West, not only carving iconic landscapes but also shaping politics and public consciousness (Reisner 1993). As Arizona faces an unpredictable but likely drier future, the search for "new" sources of potable water is perpetual. Augmenting potable water supplies is not easy, but one possibility lies in overlooked sources of water such as wastewater and saline waters.

In 2010, Arizona Governor Brewer convened the Blue Ribbon Panel on Water Sustainability (BRP) to advance water sustainability through reuse, recycling, and conservation. Among other recommendations, the BRP cited indirect potable reuse (IPR) of highly treated wastewater as a strategy to augment the drinking water supply. Although potable reuse of wastewater has long occurred incidentally across the United States, the BRP's recommendation focused on *intentional* reuse in systems where the recharge of treated wastewater is *closely coupled* with the recovery of treated wastewater for potable use (Figure 1). IPR has many benefits and thus great potential to be a so-called "new" source of water, but legal, technical, and other impediments must be resolved prior to implementing and operating any IPR system.

This white paper will first provide the broad context of IPR, including its benefits, potential risks, and a snapshot of IPR use in the United States (California, Florida, and Texas) and around the world. It will next describe the legal and regulatory landscape for IPR, focusing primarily on the Safe Drinking Water Act at the federal level and specific considerations for implementing IPR at the state level. This white paper will then detail the history, context, and status of IPR in Arizona, citing and exploring many of the legal, institutional, technical, and other obstacles to implementing IPR systems. This white paper will conclude with recommendations for implementing IPR in Arizona.

The research for this white paper was conducted by using online sources, such as peer-reviewed and grey literature and media articles, and by interviewing experts who are knowledgeable about IPR policy, permitting, operations, design, and oversight in Arizona and nationwide. A list of interviewees can be found in Appendix A, and a list of interview questions can be found in Appendix B.

An Overview of Indirect Potable Reuse

1. What is Indirect Potable Reuse?

Potable reuse refers to water that, already used once, is treated and used again as part of the drinking water supply. In the United States, surface water and groundwater are the primary and traditional sources of raw drinking water. Typically, potable water is used once in the domestic setting, and then the water is treated and discharged back into the environment or is put to beneficial use such as process cooling for power plants. This water is sometimes treated and used for agricultural and landscape irrigation, but rarely for potable use. As myriad constraints on water supply availability emerge, water providers are evaluating the future of treated wastewater as a "new" drinking water source.

Unintentional, de facto IPR has occurred for decades when downstream communities withdraw surface water into which upstream wastewater treatment plants (WWTPs) discharge

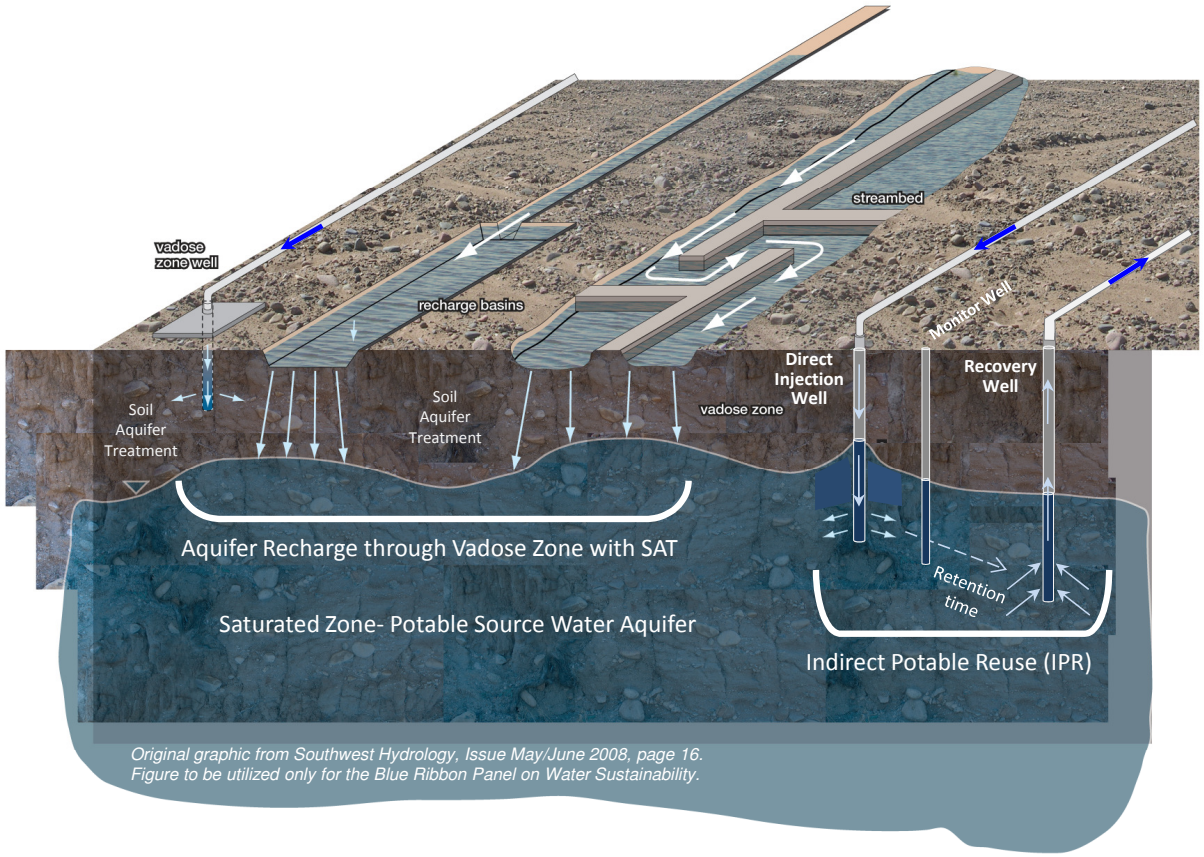


Figure 1. Diagram of a closely coupled IPR system (BRP 2010, used with permission from Gary Gin).

treated wastewater. Many major population centers in the United States draw their potable water supplies downstream of WWTP discharges, including Philadelphia and the Delaware River, Nashville and the Cumberland River, Cincinnati and the Ohio River, and New Orleans and the Mississippi River (EPA 2012). In the southwestern United States, any diversion from the Colorado River below Lake Mead—including water delivered to the cities of Phoenix and Tucson—contains treated wastewater from Las Vegas, Nevada. The U.S. Environmental Protection Agency (EPA) concluded as early as 1980 that de facto or unplanned water reuse contributes significantly to the water supply portfolio: Among the 25 drinking water treatment plants (DWTP) that receive the most upstream discharges, effluent concentrations comprised between 2 to 16 percent of those plants' water supply (EPA 1980; Rice 2013). Updated research in 2013 found that effluent contribution to the top 25 DWTPs increased by 68 percent, and under certain low flow conditions (lowest seven-day average flow every ten years, or 7Q10), de facto reuse makes up the entire flow in 10 of the 25 DWTPs (Rice 2013).

Water providers are now contemplating the *intentional* reuse of treated wastewater to augment potable water supplies. In the broadest sense, EPA defined IPR to mean "augmentation of a community's raw water supply with treated wastewater, followed by an environmental buffer" (EPA 2004). This definition describes many IPR systems in existence: Treated wastewater from a WWTP is discharged into an environmental buffer, such as a wetland or groundwater recharge basins, where the wastewater will undergo additional soil-aquifer treatment (SAT) as the water percolates through the unsaturated soil into the underlying aquifer. In contrast, *direct* potable reuse

(DPR) eliminates the environmental barrier and discharges the treated wastewater directly into the drinking water system.

The technique of closely coupling recharge and recovery is a relatively new and distinct development from existing IPR methods. It bypasses the traditional SAT process in favor of injecting the treated wastewater directly into the aquifer. The 2010 BRP defined IPR more narrowly as the "injection of advanced treated reclaimed water into the saturated zone of a potable source water aquifer…." Fundamentally, IPR is the intentional close coupling of advanced treated reclaimed water into the saturated zone of a potable water source (i.e., aquifers)" (BRP 2010).[1] Using this definition, water providers directly inject treated wastewater into an aquifer and recover potable water supplies from the same aquifer, within close proximity of the injection wells.

2. What Drives Indirect Potable Reuse?

Concerns about water supply are not new. Reduced surface and groundwater supplies due to climatic and increased human water demand have affected water availability for potable, agricultural, industrial, energy, and environmental uses, according to the U.S. Government Accountability Office (GAO 2014). To address these concerns, states are interested in developing previously ignored supplies, as well as more traditional strategies such as water conservation and efficiency. A 2014 GAO survey shows an increase in states using reclaimed water for a variety of purposes. In 2003, 23 of 47 surveyed states used reclaimed water, increasing to 36 of 50 surveyed states in 2013 (GAO 2014).

In 2012, the U.S. National Research Council (NRC) noted that the United States "has been operating near the limit of its water supply for several decades," which coupled with population growth and climate change impacts, has driven interest in developing reuse capacity (NRC 2012). Moreover, pristine sources of water that require little treatment or are inexpensive to treat are increasingly unavailable. At the same time the volume of domestic wastewater is increasing. Arguably, too, as de facto water reuse becomes common across the United States, existing drinking water and public health regulations are in effect regulating water quality from water supplies with substantial wastewater content (NRC 2012).

3. Potable Reuse around the World

Different types of intentional potable reuse systems exist around the world, from Singapore to Belgium and Australia. Singapore has a demonstration facility and other reclamation plants, while the IPR system in Wulpen, Belgium, discharges recycled water to an unconfined dune aquifer (Rodriguez et al. 2009). Australia, which has a long history of de facto IPR, is also considering making the leap to IPR (ATSE 2013). However, these systems do closely couple recharge and recovery, relying instead on recharge basins or other longer-term environmental barriers.

Interestingly, Namibia implemented a DPR system in the capital city of Windhoek that has been in operation since 1968. With low average annual precipitation of 14.4 inches, high annual evaporation of 136 inches, and few surface water resources, the facility provides enough water to meet approximately 35 percent of the city's municipal water needs (Grant et al. 2009) and up to 50 percent when water supplies are limited (NRC 2012). Although no long-term studies have been

[1] IPR includes a wide range of definitions and systems. This White Paper will adhere to an IPR definition that includes *intentional* reuse where recharge and recovery of effluent are *closely coupled* in time and space within an aquifer.

conducted on the potential effects of micropollutants in the drinking water, there have not been any obvious adverse health effects in the population of a few hundred thousand served since the system began operating (du Pisani 2006).

4. Benefits of Indirect Potable Reuse

IPR has many benefits, including being a consistent and reliable source of water, mitigating groundwater overdraft, improving water quality in existing sources of water, and maximizing the return on a community's investment in water infrastructure (BRP 2010). Unlike water sources that depend on precipitation or natural recharge, wastewater is a relatively constant or growing source of water, both in terms of overall supply and availability throughout the year. Surface water bodies and reservoirs may fluctuate with drought and climate change, and groundwater supplies may be pumped to depths where water quality is cost-prohibitive to treat, or pumping becomes cost prohibitive.

IPR, particularly systems that inject treated wastewater directly into an aquifer, simultaneously takes advantage of the aquifer as a storage reservoir, at minimal additional cost to ratepayers. Compared to groundwater recharge basins, IPR via direct injection into an aquifer is arguably better suited for rapidly urbanizing areas where the cost of land for an equivalent volume of recharged water via recharge basins would be prohibitive for many municipal water providers. IPR thus expands the options for groundwater recharge in areas where the geology is not well suited for SAT or other widely used recharge processes.

Recharging water and replenishing aquifers will also help mitigate the negative impacts of groundwater overdraft and land subsidence. A depleted aquifer may lead to land subsidence and saltwater intrusion. As water levels decline in the aquifer, zones of sand grains in the dewatered interval compact, which reduces future potential for water storage and production capacity of the well-field. The loss of pore space in the aquifer is irreversible, and continued compaction often causes land subsidence features to form at the surface. Along the coast, lowered water table levels may also lead to saltwater intrusion. To guard against intrusion, the Orange County Water District (OCWD) in southern California injects treated wastewater to replenish groundwater supplies in coastal aquifers and form barriers to saltwater intrusion. Some of that treated wastewater eventually is pumped back out and becomes part of the water supply for millions of residents (OCWD 2014).

Another potential benefit of IPR is to dilute contaminants in the receiving waterbody or aquifer. Treated wastewater today frequently meets or surpasses existing water quality standards and the water quality of receiving water bodies. According to EPA, research on the performance of several full-scale advanced water treatment operations shows that engineered systems can perform equally well or better than environmental buffers in attenuating contaminants (EPA 2012). Discharging or injecting highly treated wastewater from such systems would actually dilute contaminants in the receiving water of the environmental buffer.

IPR also maximizes the return on investment in water treatment processes and infrastructure, a valuable benefit for water providers and the communities they serve. Water is expensive to pump and transport, and frequently it is used only once before being treated and discharged. Instead of this single-pass use, IPR maximizes the potential of water by allowing a secondary or even tertiary use, eliminating the need to acquire, pump, and transport more water (WRF 2004). IPR also puts water to its highest use, human consumption. When treated wastewater

is used for residential and landscape irrigation, a community must construct and pay for additional, parallel infrastructure such as "purple pipes" to deliver treated wastewater. However, treating wastewater so that it is suitable for potable use means that the existing potable water infrastructure can be used to deliver drinking water to homes and businesses (WRF 2004).

5. Concerns about Indirect Potable Reuse

Although treating water that contains effluent is not a new challenge, the increased proportion of wastewater and number of potential contaminants in wastewater pose legitimate concerns.

One of the foremost concerns of IPR is water quality. Simply put, the source water of IPR is wastewater, which potentially contains contaminants not found in or at higher concentrations than in traditional water sources. Two contaminants of concern are total dissolved solids (or salinity) and pathogens. The salinity of recycled water increases with every pass through the water cycle, meaning that treating wastewater will produce a significant volume of brine. Disposing of this brine is a problem for water and wastewater treatment facilities, especially for land-locked facilities that cannot discharge the brine into the ocean. Treated wastewater may also have higher concentrations of organic carbon, viruses, pathogens, nitrogen, and phosphorus, as well as contaminants of emerging concern such as pharmaceuticals and personal care products.

Pathogens in wastewater are another serious concern. Technology or methods to monitor pathogen levels in real-time currently does not exist, so WWTPs do not have real-time, immediate feedback if biological contaminants such as viruses, *Giardia lamblia*, or *Cryptosporidium* are present. In some cases, up to a 48-hour delay is possible between sampling and testing results that show contamination. This delay is a significant problem for IPR systems because the contamination would affect both recharged and recovered water. Introducing inadequately treated water into potable water sources could potentially contaminate these sources, clog injection wells, or both. Disinfection technologies and methods could reduce the potential problems but also lead to others, namely creating disinfection byproducts that are difficult to eliminate and expensive to treat.

One of the most vexing obstacles for a community interested in implementing IPR is the lack of federal leadership or clear guidance in potable reuse. The federal Safe Drinking Water Act (SWDA) regulates public drinking water systems across the country, but when passed in the early 1970s few states or regulators were even considering using treated wastewater as a potable water supply. Thus, the regulatory requirements for approving such a source for a new potable water source are unclear, among other regulatory issues. State level regulations vary as well, some explicitly prohibiting direct reuse of treated wastewater for potable reuse and others remaining more ambiguous (Schempp 2010; Finley 2014; Bracken 2012). For example, a municipality in Oregon may be prohibited from reusing effluent if a downstream water rights holder can show that the reuse will interfere with those rights (Bracken 2012).

On the designing and engineering front, IPR systems essentially rely on technology to replace—in a matter of hours or days—the decades- or even millennia-long water cycle that deposits relatively clean water into surface water bodies or recharges water into aquifers. Using technology to purify water raises visceral concerns about the actual and perceived risk of consuming the treated water. At the same time, improved technologies allow laboratories to analyze water quality and detect contaminants in the parts-per-trillion concentration, but the corresponding science to determine if such concentrations are harmful is lacking (NRC 2012).

Regulators and other water professionals are similarly concerned about the potential human health risks of consuming treated wastewater. Although there have been no reported health impacts from pilot IPR projects or de facto IPR use, public perception of risk and acceptance plays a key role in implementing IPR systems. In 2012, the NRC conducted a study comparing contaminants in treated wastewater and in water supplies that are presently in use. They selected 24 contaminants in two potable reuse scenarios and found that contaminants were no higher in the treated wastewater than in existing water supplies (NRC 2012). The NRC also concluded that the risk from pathogens did not appear to be any higher, and was potentially orders of magnitude lower, in treated wastewater than in the raw water source of existing drinking water systems. However, WWTPs are not required to treat and remove *Giardia lamblia* and *Cryptosporidium*.

Beyond the science of water quality, however, is the fickle land of public opinion. Public opinion is shaped by various factors; some help drive IPR implementation and others halt it entirely. External circumstances such as drought or otherwise limited availability and yield of existing or alternative water sources can motivate a community to adopt IPR, but ultimately public acceptance is paramount (Rock et al. 2012a, 2012b). IPR is probably more palatable than DPR, but overcoming the "yuck" factor is difficult.

The Federal Landscape for Indirect Potable Reuse

One of the greatest challenges for a local community interested in implementing an IPR system is the lack of a federal legal framework or mandatory federal regulations or standards that directly apply to potable reuse. However, EPA and the NRC have published a handful of guidance documents, as have private and non-profit organizations. EPA first published *Guidelines on Reuse* in 1980 and subsequently updated the publication in 1992, 2004, and most recently in 2012. These *Guidelines* reveal EPA's evolving perspective on wastewater reuse for potable purposes and reflect the state of knowledge, technology, and research at the time of publication. The NRC has also published research on potable reuse, beginning in 1998 and updated in 2012. Both organizations have come to recognize the benefits of IPR and even DPR, at the same time remaining cautious of the wastewater origins of IPR.

Interviewees emphasized the benefits of a federal framework for IPR, such as the vast scientific and technical resources of the EPA, the showing of federal political support to bolster state efforts, and the consistency across the country that a federal framework provides. According to one interviewee, EPA brings science and credibility. The agency can draw on a number of large scientific and research resources that may not be available to states or local communities. Credibility is important to bridge the acceptance gap for both state regulators and the public. A uniform, federal framework—including rules, guidelines, or recommended practices—could help ensure consistency in how IPR is implemented by states and help build public confidence in IPR. More than one interviewee commented that a federal framework would also help quell states' concerns about IPR and thus help IPR move forward.

1. Safe Drinking Water Act

The 1974 Safe Drinking Water Act (SDWA) is the principal federal law to protect public drinking water supplies (42 U.S.C. §§ 300f et seq.). Congress subsequently made major amendments in 1986 and 1996 to protect the sources of drinking water. Similar to many federal laws, EPA sets national drinking water standards and delegates implementation and enforcement responsibility to states and Tribes (42 U.S.C. §300g-2). EPA retains oversight authority over Tribal, state, local, and

water providers' drinking water programs. The SDWA does not apply to private wells that have fewer than 15 connections or that serve fewer than than 25 individuals.

The SDWA defines both Primary and Secondary Drinking Water Standards. Primary standards are legally enforceable standards that apply to public water systems (PWS) (42 U.S.C.A. § 300g-1). A PWS is any water system with at least 15 connections or that regularly serves an average of at least 25 people per day for at least 60 days per year. The standards address contaminants such as microorganisms, disinfectants, disinfection byproducts, inorganic chemicals, organic chemicals, and radionuclides. Secondary standards for drinking water, which are not mandatory, have been set for 15 contaminants. These contaminants are not considered a risk to human health. Instead they address aesthetic considerations, such as the taste, color, and odor, of drinking water (EPA 2004).

Setting primary drinking water standards occurs in three phases: First, EPA identifies contaminants that may adversely affect public health and occur in drinking water with a frequency and at levels that pose a threat to public health. That is, contaminants that both in theory and actually pose threats to public health. EPA then identifies contaminants for detailed study and determines which ones to potentially regulate. Second, EPA sets a maximum contaminant level goal (MCLg) for the regulated contaminants. The MCLg is "the level of a contaminant in drinking water below which there is no known or expected risk to health," accounting also for a margin of safety. Third, EPA specifies a maximum contaminant level (MCL), or the maximum concentration of a contaminant allowed in public drinking water. The MCL is set as close to the maximum contaminant goal as feasible. The term "feasible" means "the level that may be achieved with the use of the best technology, treatment techniques, and other means" and that accounts for cost.

If the MCL is not economically or technically feasible, or if there is no reliable economic method to detect contaminants in the water, EPA may also specify a treatment technique to remove contaminants (42 U.S.C.A. § 300g-1; EPA 2004). The treatment technique is an enforceable procedure or level of technological performance. PWS are required to follow the treatment technique to control pathogens and other contaminants, as well as specific monitoring, recordkeeping, and reporting requirements. One interviewee emphasized that these requirements are non-trivial and help explain why WWTPs are not equivalent to surface water treatment facilities with respect to treatment stringency and water quality.

In the 2004 *Guidelines for Reuse*, EPA noted that the original purpose of the national primary drinking water standards was not intended to define potable water quality when the source is municipal wastewater. EPA also noted that detection technology has dramatically improved: The chemicals regulated by the SDWA are a small fraction of the hundreds of thousands of manufacturing chemicals in use today (EPA 2004). However, information to identify all potential contaminants at concentrations of health significance is lacking, despite the ability to detect them. Newer contaminants include endocrine disrupters, pharmaceuticals, hormones, antibiotics, anti-inflammatory substances, and personal care products—none of which are regulated or monitored by the MCLs.

2. Source Water Assessment Program

One of the major amendments of the SDWA established the Source Water Assessment Program (SWAP), expanding protection to the *sources* of drinking water. "Source water" is defined as untreated water from streams, rivers, lakes, or aquifers that supply private wells and public drinking water (EPA OIG 2005). The SWAP helps a state gather information about its drinking

water sources so that it can better protect them through regulations, public education efforts, land acquisition, conservation easements, or land-use regulations.

To implement this information-gathering and data-collection program, a state must first delineate the source water assessment area by mapping the land area that contributes to the water supply and pollutants. For surface water, this includes the watershed upstream of the drinking water intake point, which encompasses the area contributing precipitation to the drinking water source. For groundwater, a state can use information about groundwater flow or simply draw a circle of a prescribed radius around each source well. Next, a state must conduct an inventory of potential sources of contamination. This inventory includes information such as: How likely is a water supply to be contaminated by an identified potential source of contamination? Local groups may provide information about contaminant sources, water resource characteristics, or environmental management practices. After compiling this information, a state is required to make the assessment available to the public.

For IPR systems, the SWAP raises specific issues and questions. First, the SDWA limits drinking water sources to traditional sources, namely surface water and groundwater. Treated wastewater is not mentioned as a potential source of drinking water. Second, in the SWAP process, it may also be difficult to delineate the source water assessment area for IPR. Is the source the WWTP? Is it the entire wastewater conveyance system? Is it the aquifer where the treated wastewater is injected?

3. Clean Water Act

Unlike the SDWA's focus on human health, the federal Clean Water Act (CWA) focuses on the chemical, physical, and biological integrity of waters across the country.[2] The goal of the CWA is to promote fishable and swimmable waters, primarily by controlling water pollution through end-of-pipe, technology-based controls for discharging water into the environment. Certain facilities and other sources of water pollutants are subject to the National Pollution Discharge Elimination System (NPDES) permitting program. EPA sets uniform, nationwide technology-based limitations for a particular industry or sector, regardless of where the polluter is located. That is, EPA sets minimum limitations that all water polluters must meet, regardless of the water quality of the receiving waters into which a polluter discharges. The Total Daily Maximum Load (TMDL) program accounts for the water quality of receiving waters and provides tailored standards for certain waterbodies.

One of the most important CWA programs related to IPR is the National Pretreatment Program, which sets treatment standards for certain industrial dischargers before they send their wastewater to publicly owned wastewater treatment plants (POTWs).[3] POTWs are primarily designed to treat domestic sewage, such as typical household waste, biodegradable commercial waste, and biodegradable industrial waste. These wastes generally contain conventional pollutants: biological oxygen demand (BOD), total suspended solids (TSS), fecal coliforms, pH, and oil and grease. Yet they also receive wastewater from the industrial sector, such as the pulp and paper industry, iron and steel manufacturing, and battery manufacturing. Pretreatment regulations

[2] The Clean Water Act applies to "waters of the United States," which to date effectively refers to surface water bodies.
[3] POTW refers specifically to publicly owned wastewater treatment plants; WWTP refers generally to all wastewater treatment plants, which may or may not be publicly owned and may or may not have the capacity to treat industrial wastes.

control pollutants from these sectors prior to those discharges reaching a POTW and can therefore help protect the quality of wastewater.

To regulate pollutants from industrial users, the National Pretreatment Program requires all large POTWs (designed to treat more than five million gallons per day (MGD)) and smaller POTWs that accept wastewater from industrial users to establish local pretreatment programs. These programs must enforce all national pretreatment standards and requirements, as well as other specific local conditions needed to protect site-specific conditions at the POTW. Industrial users must obtain permits and implement certain control mechanisms prior to discharging wastewater to a POTW.

Two important exemptions to the National Pretreatment Program may affect closely coupled IPR systems. First, public utilities that are not owned by a government entity are not required to have a pretreatment program. Second, POTWs with flows less than 5 MGD are also exempt. Either type of facility would have to implement its own pretreatment program prior to receiving approval to operate an IPR system.

4. Reconciling the Safe Drinking Water Act and the Clean Water Act

The SDWA and the CWA regulate water quality nationwide but focus on different end uses. These laws and their standards apply at different points in an IPR system. For recharged waters, discharged into waterbodies or aquifers, the CWA or state standards pursuant to the CWA apply. For recovered waters, destined for potable use, SDWA standards and regulations apply. The SDWA addresses water quality for drinking water purposes, whereas the CWA is protecting water quality for a wide range of chemical, physical, and biological factors for environmental purposes. The CWA water quality standards are generally more stringent than SDWA water quality standards, but they do not regulate contaminants for human health. IPR invokes both CWA and SDWA programs. For example, when an upstream WWTP discharges treated wastewater into a river, that water must comply with CWA NPDES requirements. Then, when a downstream water provider recovers that water for drinking water purposes, that water must be treated again to comply with SDWA standards.

The technological treatment standards under the two federal programs are also different, which is reflected in differences in how a state administers the various programs. For example, the federal CWA specifies certain treatment technologies for wastewater to meet the goals of the CWA: to restore the chemical, biological, and physical integrity of the waters of the United States. The SDWA has a narrower focus on drinking water, and EPA sets the standard for treating drinking water. For treating raw source water, the standard is the Best Available Technology (BAT). As administered by Arizona, the standards between the two federal laws serve different purposes, leading to key quality differences between recharged and recovered water. The treatment processes used by WWTPs for water that is *recharged* does not conform with the requirements for drinking water under the SDWA when that water is later *recovered*.

As discussed below, an analogous situation occurs in Arizona for water recharged into and recovered from an aquifer, and the discrepancy between the two sets of standards—in terms of constituents, concentration levels, and monitoring and reporting requirements—contributes to much of the regulatory redundancy and duplication that poses a problem for IPR.

Table 1. Sample Differences in Regulatory Permits and Programs for Recharged and Recovered Water.

Recharged Water	EPA NPDES permit[4] or state APP; Underground Injection Control
Recovered Water	ADWR Underground Storage Facilities Water Storage Facilities Recharge Well permitting program

State Considerations for Indirect Potable Reuse

In addition to the federal laws and regulations, a state must also consider its own legal framework. IPR implicates laws and regulations related to water quality, water rights, water supply management and allocation, wastewater use and rights, land use, and public health. Each of these may have a significant impact on IPR. For example, one interviewee commented that, at the national level, hesitation from some states about water rights and allocation of wastewater is an obstacle to developing federal framework.

Water rights—and the allocation and allowed uses of water—are an important consideration for IPR, particularly in western states that follow the doctrine of prior appropriation. States generally follow one of two systems of surface water allocation in the United States: In eastern, wetter states, the doctrine of common law riparianism prevails, whereby rights to use water are correlative with other riparian users. The quantity of water is not specified, but water must be used reasonably and not to the harm of other users. In western, more arid states, the doctrine of prior appropriation prevails, whereby the user who is first in time is first by right. For groundwater, states follow a variety of doctrines that generally do not correspond to their geographic location within the United States or surface water laws (Dellapenna 2013).

In western states, reclaimed water may a more reliable supply than surface waters because water for domestic and other uses that generate wastewater—roughly one-third of which reaches a WWTP—are relatively uninterrupted and constant throughout the year (EPA 2004a). Thus, reclaimed water may constitute the largest block of unappropriated water in the western United States (EPA 2004a). How a state classifies and regulates the use of reclaimed water is important (Stein et al. 2011). Rights to use water allocated by prior appropriation have specific requirements for the use itself as well as the time and place of use. For example, if the designated use were limited to public water supply, a WWTP could be required to return flows into a nearby stream. Changing a single aspect could violate the legal use of water. Such a change may also affect the rights of junior users, ultimately constraining a state's ability to implement IPR. A state may also have specific legislation or case law governing the use of effluent, independent of the water allocation laws (Bracken 2012; Schempp 2010).

Other considerations include state-specific provisions to implement federal water quality programs under the SDWA and the CWA. Those programs must be compatible and consistent with federal standards and minimum requirements, but a state may adopt more stringent requirements to address specific local concerns. A state must also consider land use ordinances and permitting requirement for construction of IPR facilities, as well as any additional measures to protect public health.

[4] If a WWTP does not discharge to a waterbody regulated by the CWA, then a NPDES permit or state equivalent is not needed. According to one interviewee, quite a few Arizona WWTPs do not possess a NPDES permit because their discharge goes entirely to either reuse or recharge, which reduces the regulatory complexity.

Potable Reuse around the United States

A handful of states such as California, Texas, and Florida have potable reuse projects that are intentional but, unlike some of the proposals in Arizona, are not closely coupled via an aquifer. They generally rely on SAT, advanced water treatment processes (such as membrane filtration or UV oxidation), or other environmental barriers before the treated wastewater is recovered as drinking water. This section examines IPR systems in these states as well as the regulations governing potable reuse of treated wastewater.

1. California

California is experiencing a severe and historic drought, prompting a mandatory statewide reduction in water use and forcing regions to look for alternative water supplies. However, California has had intentional IPR in practice since 1962. Multiple agencies are responsible for oversight, including the Department of Public Health, the State Water Resources Control Board, and Regional Water Quality Control Boards.

The California Code of Regulations (CCR) distinguishes between groundwater replenishment through surface application, such as spreading basins where water percolates through the unsaturated soil into the aquifer, and subsurface application, which includes all non-surface applications such as direct injection (22 CCR §§ 60301.840, 60301.850). Effectively, a groundwater replenishment project in California must provide an alternative drinking water supply if the water used for the replenishment project (1) violates a state or federal drinking water standard, (2) has been degraded to the degree that it is no longer a safe source of drinking water, or (3) fails to meet requirements for pathogenic microorganism control (22 CCR § 60320.200). Prior to any project receiving approval for going forward, California regulations have many monitoring, sampling, and reporting requirements such as:

- Controls for wastewater source, pathogenic microorganisms, regulated contaminants, physical characteristics, and nitrogen;
- Requirements for diluent water, total organic compounds (TOCs), SAT treatment processes, and other chemical and contaminant monitoring;
- Operational plans and requirements for operating groundwater replenishment projects;
- Requirements for monitoring wells and laboratory analysis of water samples;
- Requirements for regular reporting; and
- Requirements for public hearings and notice of treated wastewater use.

For example, California regulations require the source wastewater to come from a WWTP that operates an industrial pretreatment program and from a water provider that maintains a source control program (22 CCR § 60320.206). This program, at a minimum, must include an outreach program to industrial, commercial, and residential communities within the portions of the sewage collection system (22 CCR § 60320.206). A proposed groundwater replenishment project must be designed and operate operate treatment processes that achieves "at least 12-log enteric virus reduction, 10-log *Giardia lamblia* cyst reduction, and 10-log *Cryptosporidium* oocyst reduction," consisting of at least three separate treatment processes (22 CCR § 60320.208). Total nitrogen concentration must be maintained below 10 mg/L, and reduced monitoring frequently is permitted for consistently demonstrating and maintaining a total nitrogen concentration below 5 mg/L (22 CCR § 60320.210).

California regulations also specify a response retention time: Treated wastewater must be retained underground "for a period of time necessary to allow a project sponsor sufficient response time to identify treatment failures and implement actions" and "no less than two months" (22 Cal. Code Reg. § 60320.124). Retention time in the aquifer qualifies for log-removal credit, meaning that one month of retention time equals one-log removal for pathogens; a maximum of six-log removal credits for a retention time of six months can be obtained.

California regulations also require an engineering report, which one interviewee noted is a strength of the regulations. The Engineering Report describes the design of the proposed groundwater replenishment project system and must clearly indicate how the project will comply with regulatory specifications. The Report must also include a contingency plan that ensures no untreated or inadequately treated water will be delivered for potable use.

The Orange County Water District (OCWD), established by legislation in 1933, has long led the state—and the country—in augmenting water supplies with treated wastewater. The OCWD manages the groundwater basin for more than 20 water producers that serve more than 2.7 million residents and groundwater users. The treated wastewater serves two primary purposes: as a barrier against salt water intrusion along coastal aquifers in the OCWD service area and to maintain groundwater supplies for all water users in the OCWD service area, including water for potable use.

From 1976 until 2004, the OCWD operated Water Factory 21, which produced 19 MGD of treated wastewater (OCWD 2004). In 2008, the OCWD began operating the Groundwater Replenishment System (GWRS), which produces 70 MGD and is expected to increase to 100 MGD in 2015 and ultimately to a maximum capacity of 130 MGD (OCWD 2004). The GWRS treats wastewater using conventional primary and secondary treatment, as well as advanced treatment processes—specifically, reverse osmosis, microfiltration, and UV disinfection techniques. The wastewater would otherwise undergo conventional treatment and be discharged into the Pacific Ocean. With advanced treatment, the wastewater maybe of better water quality than required by state and federal drinking water standards. The OCWD both injects and discharges the treated wastewater into inland spreading basins, where the treated wastewater eventually returns to the aquifer as part of the drinking water supply and pumped from down-gradient water supply wells (Gale 2013).

2. Texas

The lack of alternative water supplies under the current drought has led to two instances of DPR in Texas: the Colorado River Municipal Water District (CRMWD) and the city of Wichita Falls (Martin 2014). In May 2013, the CRWMD began operating a WWTP that produces 2 MGD of treated wastewater that meets drinking water standards. Similar to the Orange County GWRS in California, the treatment train includes advanced treatment: microfiltration, reverse osmosis, and UV disinfection. The treated water is added to a raw water pipeline that contains surface water from a lake. The final water mix is 20 percent treated effluent and 80 percent raw water, which is distributed to drinking water facilities where it undergoes additional treatment. The water is distributed to 250,000 residential users in Odessa, Big Spring, Snyder, and Midland, cities located along I-20 between Dallas-Fort Worth and El Paso. For the CRWMD, this DPR system was necessary because there was no space to build additional surface reservoirs and most of the fresh groundwater was already developed (Martin 2014). IPR via recharge basins was also not viable because of the low infiltration rate and high rate of evaporation.

Wichita Falls faced a similar dilemma and opened a DPR plant in June 2014. The plant produces up to 10 MGD. Here, brackish surface waters from a lake already required microfiltration and reverse osmosis to treat drinking water supplies, so the city simply built a 13-mile aboveground pipeline to connect the WWTP to the drinking water plant. The system mixes 50 percent treated effluent and 50 percent surface water, and the mixture is treated again before serving 150,000 residents.

In both cases, the potable reuse projects were developed without a state regulatory framework. Instead, the water providers worked with the Texas Commission on Environmental Quality (TCEQ) to develop guidelines, which included extensive testing and verification of the final water supply. For example, the water in Wichita Falls initially missed the standards for trihalomethane (a disinfection byproduct), nitrates, and microbes. By adding advanced treatment at the WWTP, the water eventually met the required standards.

3. Florida

Groundwater is the primary source of potable water in Florida, and it originates from the Floridan aquifer. In 2010, public water supplies and self-supplied domestic water accounted for 56 percent of the total fresh groundwater withdrawn (Maupin 2014). In Florida, reuse projects were historically used for effluent disposal, but in the late 1970s the demand for water supplies increased. As a result, interest turned to treated wastewater as a drinking water supply.

The Florida Administrative Code (FAC) directly addresses groundwater recharge and indirect potable reuse. Water quality standards depend on the class of the receiving groundwater: For the highest class of water, recharged water must meet federal primary and secondary drinking water standards. Regulations also depend on whether the system is augmenting surface water supplies or recharging groundwater by direct injection. For surface water, the water quality limits and treatment requirements are less stringent because the water will receive additional SAT. If, however, the underlying geology means that the recharged water moves more quickly through the vadose zone, there are stricter requirements (NRC 1988; FAC r. 62-610.200(27)). Potable reuse via direct injection has stricter requirements for detectable levels of fecal coliforms, total suspended solids, and chlorine residuals (NRC 1998).

Florida also requires an engineering report, describing the location, soils information, hydrogeological survey information, and a project evaluation that shows the long-term effect of the proposed project on environmental resources, among other aspects.

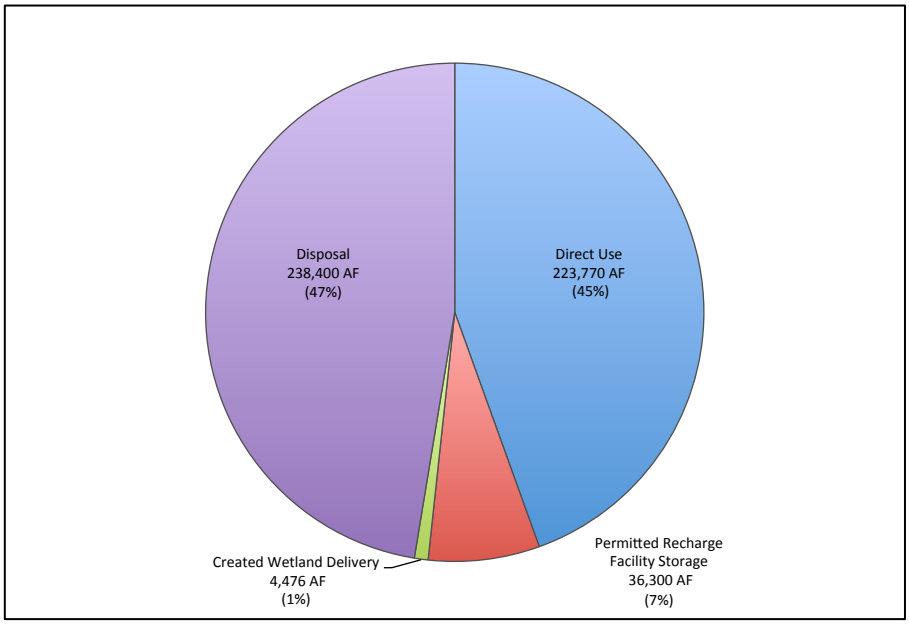
An Overview of Indirect Potable Reuse in Arizona

Earnest discussion of IPR in Arizona began with the 2010 Blue Ribbon Panel on Water Sustainability. This section will discuss the potential and challenges for IPR in Arizona.

1. Effluent in Arizona

Since the beginning of statehood, the arid climate in Arizona has forced water managers and state leaders to implement creative solutions to provide water to support the state's economy and growing population.

Figure 2. Effluent Use in Arizona (ADWR 2008).



The primary source of effluent is indoor residential or commercial water use. Between 2001 and 2005, municipal water demand made up 35 percent of the state's water use, the majority of which is residential use (ADWR 2010). In the city of Phoenix, approximately two-thirds of the water used is for residential purposes and a sizable proportion of that is used for outdoor irrigation (Balling and Gober 2007).

Effluent use in Arizona makes up approximately three percent of the total water use, which mainly consists of surface water (54 percent) and groundwater (43 percent). In the state's Active Management Areas, five regions in the state where groundwater use is restricted, effluent use makes up slightly more—four percent—of the total water use, and groundwater use is slightly less (ADWR 2010). In 2006, data from 53 percent of wastewater facilities in Arizona showed that they produced 502,946 acre-feet (AF) of effluent, much of which was used for agricultural irrigation, golf and turf irrigation, and industrial use (ADWR 2010).[5] Figure 2 shows how this effluent was used: the majority—238,400 AF—was disposed of, 233,770 AF was for direct use, 36,300 AF was for permitted recharge facility storage, and 4,476 AF was for created wetlands. Statewide, the vast majority of effluent is generated in and around Phoenix and Tucson.

Aquifer recharge is an important part of Arizona's water management strategy. The typical recharge system consists of recharge basins or vadose wells, allowing the water to undergo soil-aquifer treatment (SAT)—a form of additional treatment—as the water moves from the unsaturated zone to the saturated zone (BRP 2010). SAT is widely accepted as a method of secondary treatment to remove all biological organic constituents (BRP 2010). Nevertheless, in Arizona, all reclaimed water must meet regulatory standards at the point of discharge, regardless of additional SAT.

For purposes of water rights and allocation, the Arizona Supreme Court has ruled that effluent is a distinct source of water, legally distinguishable from surface water and groundwater. In

[5] ADWR (2010) notes that the data accounts for approximately 53 percent of the total treated wastewater generated in Arizona.

Arizona Public Service Company v. Long, the court concluded that effluent remains a distinct source of water until it is "returned to the ground as surface water or groundwater," after which it may be appropriated according to state surface water or groundwater laws. In this case, the court ruled that a city or other entity that produces treated wastewater can use that wastewater as it sees fit. The city is not required to discharge it for junior or downstream users (773 P.2d 988 (Ariz. 1989)). The court recognized the benefits of recycled water: Allowing a city to use its effluent for any reasonable use "as it sees fit" allows it to "maximize [its] use of appropriated water and dispose of effluent in an economically feasible manner." *Id.* This reuse also "provides a degree of flexibility that is essential to a city's ability to meet federal and state environmental and health standards." *Id.* However, the court emphasized that a city that produces treated effluent does not and cannot *own* the water, which remains a precious and public commodity and available only for beneficial use. *Id.*

2. Blue Ribbon Panel on Water Sustainability

In 2010, Governor Brewer convened a Blue Ribbon Panel on Water Sustainability, whose purpose was to "advance water sustainability statewide by increasing reuse, recycling, and conservation to protect Arizona's water supplies and natural environment while supporting continued economic development and to do so in an effective, efficient and equitable manner" (BRP 2010). The focus areas were (1) to increase the volume of reused, reclaimed water as a substitute for raw or portable, (2) to advance water conservation and increase efficiency, (3) to reduce the energy needed to produce and use reclaimed water, (4) to reduce the amount of water needed to generate energy, and (5) to increase public awareness and acceptance of reclaimed and recycled water uses and the overall need to achieve water sustainability (BRP 2010).

The BRP issued White Paper #10, "Facilitating Indirect Potable Reuse," which recognized that recycled water supplies in Arizona are underused and concluded that efforts "should be made to manage water supplies to optimize the match between water quality and intended uses" (BRP 2010). The paper called for definitions and guidance to clarify and facilitate drinking water source approval and local and state agency permitting requirements, which would lead to standardized and efficient approach to designing, permitting, and operating IPR design.

The BRP also identified both infrastructure and regulatory impediments to implementing IPR in Arizona. For example, the rule on minimum design criteria for a PWS includes a 100-foot rule that, according to the BRP, "does not address the physical structure of the aquifer and the affects [sic] of IPR recharge and recovery activities." The current rules also do not consider how new technologies could adequately treat reclaimed water to prevent biological regrowth or reduce the need for post-treatment disinfection, which could lead to formation of disinfection by-products in the aquifer.

Ultimately, the White Paper identified the need for a unified, statewide IPR policy. The BRP recommended (1) the creation of a multi-agency steering committee, charged with developing a unified, statewide IPR policy, (2) the creation of an IPR advisory panel to address new technologies and methods, as well as public acceptance of IPR, and (3) an open and transparent public rule-making process for developing the IPR framework (BRP 2010).

In the years since the BRP issued its report and White Paper #10, a statewide policy on IPR has not been developed. However, other developments are promising. In 2014, ADWR specifically identified the "need to explore and invest in direct potable reuse for drinking water supplies" in its strategic vision for water supply sustainability (ADWR 2014). Anecdotally, one interviewee noted a

de-emphasis on constructing purple pipes, the infrastructure that delivers reclaimed water for landscape irrigation purposes, from 2010 to 2015. The interviewee noted that in 2010 there was a great deal of focus on building this parallel water delivery system but observed that now cities in Arizona are questioning this strategy. According to this interviewee, cities are realizing that it is less expensive to use the existing water delivery structure to deliver potable water and may make the leap to IPR or DPR by constructing a pipe from the wastewater discharge facility to the potable water treatment facility or recharge facility.

The primary recommendation that emerged from White Paper No. 10 was the need for a statewide policy. However, the mindset of at least one interviewee has changed with more experience in the intervening years. This interviewee emphasized that Arizona has a good permitting framework, including some flexibility that a statewide system should retain. Although a unified, statewide system would expedite the development and construction of IPR systems, this interviewee noted that under the current system it is possible to implement IPR, even though it may not be straightforward.

Impediments to Indirect Potable Reuse in Arizona

The following sections will detail the legal and regulatory, institutional, technical design and performance, and other impediments, obstacles, or concerns that interfere with developing, constructing, and operating IPR systems in Arizona, focusing on Maricopa County and Phoenix.

One of the main obstacles to implementing IPR is public acceptance, as noted by the BRP. However, opinions may be changing. For example, an interviewee observed anecdotally that public awareness of potential water shortages has increased as concern has mounted about a potential shortage on the Colorado River and its impact on southern Arizona. Nevertheless, this interviewee noted that the contagion mentality in the public mind is persistent and difficult to overcome: Once water is contaminated, it remains so (Robinson et al. 2005; Rock et al. 2012a).

1. Institutional Overlap

In Arizona, a handful of federal, state, and local agencies play important roles in regulating drinking water and related water management. Arizona falls under the jurisdiction of EPA Region 9, which provides oversight of state programs that implement federal drinking water and water quality laws, regulations, and programs. At the state level, the Arizona Department of Water Resources (ADWR) and the Arizona Department of Environmental Quality (ADEQ) both have oversight responsibilities related to IPR systems. As discussed below, the ADWR provides hydrogeological information about aquifers and issues the Underground Storage Facility permit. It also helps manage groundwater in the five Active Management Areas in Arizona, designated by the 1980 Groundwater Management Act. ADWR is also the lead agency for the SWAP. ADEQ oversees water quality programs for surface water and groundwater and issues the Aquifer Protection Permit (APP).

At the local level, ADEQ has delegated to Maricopa County the authority to enforce SDWA and additional state requirements for PWS. At the county level, the Drinking Water Program is housed within the Maricopa County Environmental Services Department, which has a key role in approving a new source of water for water providers.

The BRP and interviewees cited significant institutional and regulatory overlap as an impediment to IPR. The BRP noted the "multiple layers of overlap related to the design, construction, and operations of the facilities, hydrogeological characterization of the area, monitoring well design and location, water quality sampling and reporting requirements, water quality impacts, groundwater level impacts, technical and financial capabilities of the applicant, and land ownership and land zoning issues" (BRP 2010). At least four different agencies operate at the federal, state, and local levels (Table 2).

Table 2. Regulatory Requirements for IPR in Arizona.

Agency	Permit or Oversight Role
U.S. EPA Region 9	General oversight
Arizona Department of Environmental Quality	Aquifer Protection Permit Approval of Source Water[+] Approval to Construct (Drinking Water)[+] Approval of Construction (Drinking Water)[+]
Arizona Department of Water Resources	Underground Storage Facility Permit[6] Water Storage Permit[7] Recovery Well Permit[8] Service Area Permit
Maricopa County Environmental Services Department	Approval of Source Water Approval to Construct for drinking water and wastewater facilities Approval of Construction for drinking water and wastewater facilities

2. *Legal and Regulatory Impediments*

In Arizona, the primary legal obstacles to implementing IPR are the explicit lack of statutory authorization, unclear statutory language, and an onerous permitting process with overlapping or inconsistent requirements.

a. *Reclaimed Water Use*

One interviewee suggested that there is some ambiguity about whether IPR is specifically prohibited under Arizona regulations. Section R18-9-704(G) of the Arizona Administrative Code (AAC) explicitly says that *direct* reuse for human consumption is prohibited. There is no statutory prohibition applicable to *indirect* reuse for human consumption, but there is also no definition for "direct." Depending on the environmental barrier, IPR could arguably run afoul of this provision.

[+] ADEQ has delegated permitting authority in Maricopa and Pima Counties; the agency issues these permits for all counties except Maricopa and Pima.

[6] An Underground Storage Facility permit applies to a facility that directly recharges water underground. The applicant must demonstrate (1) the financial and technical capability to construct and operate the facility, (2) the hydrologic feasibility of the project, (3) no unreasonable harm to land or other water users, and (4) necessary floodplain use permits have been obtained (A.R.S. § 45-811.01).

[7] A Water Storage Permit is required for an entity that seeks to store a specified amount of water in a specific storage facility. An applicant must demonstrate the right to use the stored water and an inability to use the water directly (A.R.S. § 45-831.01).

[8] A Recovery Well Permit is required to use water stored in a storage facility. The water may be recovered from a permitted recovery well in the area of impact of the storage area (A.R.S. § 45-834.01). The "area of impact" is calculated annually based on actual recharge and recovery volumes from the prior year. Recovery outside the area of impact may be permitted under certain circumstances.

ADEQ distinguishes among different classes of reclaimed water and issues general and individual permits for reclaimed water reuse.[9] Currently in Arizona there is no class of reclaimed water that designates IPR as a use. ADEQ may issue an individual permit for the reuse of industrial wastewater that contains sewage or that is used in processing any crop or substance that may be used as human or animal food. Reclaimed water, is divided into three classes—A, B, and C—with an additional designation of "+" possible for the A and B classes (AAC R-18-11-301 et seq.). Class A reclaimed water is for non-potable reuse applications suitable for open access by the general public, in other words, where treatment has reduced exposure to potential pathogens. Classes B reclaimed water is for non-potable uses where access to the general public is restricted. Class C reclaimed water is for even more restricted uses. The "+" designation for Classes A and B indicates that the total nitrogen concentration is less than 10 mg/L.

Arizona regulations neither explicitly prohibit nor allow *indirect* potable reuse. From a water quality perspective, the reclaimed water regulations generally do not allow reuse that has the potential for human contact, much less direct human consumption. From a water allocation and use perspective, state law does not mention potable reuse as a beneficial use under of surface water. Those uses are limited to domestic, municipal, irrigation, stock watering, hydropower, recreation, wildlife, non-recoverable water storage, and mining (ARS § 45-151(A)). This underlying tension may need to be resolved by the state legislature prior to going forward with any IPR system.

a. Rule on Minimum Design Criteria

Interviewees and the BRP itself cited as a major obstacle the administrative rule, "Minimum Design Criteria for a Public Water System" (AAC R18-5-502). This rule states: " A public water system shall not construct or add to its system a well which is located within 100 feet of a discharge or activity which is required to obtain an Individual Aquifer Protection Permit." The BRP commented that this rule does not address the physical structure of the aquifer and the effects of IPR recharge and recovery activities (BRP 2010). The blanket 100-foot prohibition may be both over- and under-inclusive, failing to account for an individual aquifer's structure, treatment potential, or attenuation capability (BRP 2010).

Some interviewees agreed that the wording of this rule is vague and confusing. For example, "discharge or activity" could include a system with a primary discharge well and multiple monitoring wells, raising the question of where the 100-foot boundary applies. Another interviewee explained that, in practice, an Individual APP is issued to a facility that discharges water that could affect water quality in an aquifer. The APP defines the boundary of the facility, and the rule prohibits a drinking water well connected to a PWS from being constructed within 100-feet of a facility that has an Individual APP. Monitoring wells do not discharge, so the minimum distance does not apply.

b. Aquifer Water Quality Standards & Aquifer Protection Permits

ADEQ regulates the water quality of discharges into the aquifer through aquifer water quality standards (AWQS) and Aquifer Protection Permits (APP). These standards are the state analogue to surface water quality standards under the federal CWA (ARS § 49-223; AAC R18-11-

[9] There are nine types of general permits, ranging from domestic greywater reuse permits that do not require a notice-of-intent and do not expire if permit conditions are continuously met, to Types 2 and 3 general permits that require NOI, expire after five years, and may require explicit ADEQ approval.

401 et seq), and they are entirely state-based. All aquifers in Arizona are classified and protected for drinking water use. A discharger is required to have a permit (discussed below) and cannot cause or contribute to a violation of AWQS.

Similar to the federal water quality standards in the NPDES program, Arizona has both numeric and narrative water quality standards for discharges of water into an aquifer. The numeric standards are specific concentrations of pollutants, above which discharges are prohibited from containing (AAC R18-11-405). Narrative water quality standards are a general prohibition on pollutants in discharge water: "A discharge shall not cause a pollutant to be present in an aquifer classified for drinking water protected use in a concentration which endangers human health… [or] cause or contribute to a violation of the water quality standard [for surface waters]." The narrative standards also prohibit pollutants in water discharged into an aquifer that impair "existing or reasonably foreseeable uses of water in an aquifer." AWQS do not protect against contamination by pathogens, in contrast to the SDWA's Primary Drinking Water Quality Standards.

ADEQ administers the APP system, a state-based groundwater analogue to the federal NPDES permitting program. Any owner or operator of a facility that discharges a pollutant directly into an aquifer, to the land surface, or to the vadose zone with reasonable probability that the pollutant will reach an aquifer is required to have an APP (ARS § 49-201(11), 49-241). Some categories of facilities, such as injection wells and surface impoundments, are specifically regulated, while others are exempt. ADEQ issues both general permits for categories of facilities and individual permits for individual dischargers. An APP requires an applicant to demonstrate that AWQS will not be exceeded at the point of compliance or will not be further degraded, if the aquifer is already not in compliance. It also requires the applicant to use best available demonstrated control technology (BADCT) to treat the discharged water, and the applicant must demonstrate that it has the financial and technical capability to comply with the APP.

Although the AWQS and APP program protect groundwater in Arizona, they give rise to regulatory impediments when applied to IPR. Interviewees cited the discrepancies in the standards—for inorganics, organics, and radionuclides—between federal SDWA standards and state AWQS (Table 3). The problem manifests in the timing of recharge and recovery: Recharged water must meet APP standards at a point of compliance in the aquifer, but when recovered all users would have to treat the water again to meet SDWA standards for drinking water use. Because the AWQS program is a state program, rather than state implementation of a federal program, the AWQS can be set at any level with no applicable federal minima. For many but not all contaminants, the AQWS are effectively set at the federal minima. Table 3 illustrates some of the differences between federal and state standards.

Table 3. Differences between federal and state water quality standards in Arizona.

Pollutant	SWDA Standard	AWQS
Arsenic	0.01 mg/L	0.05 mg/L
Bromates	0.01 mg/L	Missing
Chlorite	1.0 mg/L	Missing
Haloacetic Acids	0.06 mg/L	Missing
Trihalomethanes (total)	0.08 mg/L	0.10 mg/L
Uranium	30 pCi/L	Missing

Another discrepancy is that the numeric AWQS do not address the federal, non-mandatory secondary drinking water standards. For example, the numeric AWQS and the primary SDWA standard for fluoride is 4.0 mg/L, and the secondary SDWA standard for fluoride is 2.0 mg/L. If reclaimed water met the primary standard—say, at a fluoride concentration of 3.0 mg/L—but did not meet the secondary SDWA standard, the drinking water utility would have to give public notice that the secondary standard was violated or further treat the recovered water before adding it to the drinking water supply. Standards for arsenic and trihalomethanes were updated under the SDWA in 2006 and 2003, respectively, but were not updated for the AQWS.

c. Reporting Requirements and Points-of-Compliance

The handful of permits for determining water quality, whether to fulfill federal drinking water requirements or state aquifer requirements, differ in reporting requirements. This difference includes the timing of reporting and the format of reporting, even if the information content is the same. Interviewees noted that these differences generate time-consuming amounts of redundant work. For example, recharging water requires permits from both ADWR and ADEQ for different purposes: the quantity of recharged water and the quality of recharged water, respectively.

The difference arises from the goals of the overarching federal laws, the CWA and the SDWA. For the CWA, the point of compliance is located at the WWTP where it discharges treated wastewater, whether into a waterbody or into the reclaimed water distribution system. For the SDWA, the POC is generally located where the drinking water leaves the DWTP or at the well site.

Table 4. Reporting Requirements for State and Federal Water Regulations.

Water Regulation or Permit Program	Report Contents	Reporting Frequency
APP Self-Monitoring and Reporting Forms (SMRF)	Contaminants (such as coliforms, asbestos, inorganic chemicals, radionuclides, lead and copper, and bromate) Volumes	Quarterly, in general
SDWA[10]	Array of water quality contaminants Treatment Technique monitoring Monitoring source water for *Cryptosporidium* and other pathogens	Quarterly, biannually, and annually

d. Operator License or Certification

The BRP White Paper and interviewees cited the need for an operator license or certification specific to IPR systems. Although IPR does not necessarily present a new challenge, it is more complex and may be unfamiliar to distributors and operators of more traditional sources of drinking water. The knowledge of the latter is not readily transferrable to IPR systems. At the county level, the Maricopa Environmental Health Code requires a certified operator, but ADEQ does not. Certification is necessary to ensure proper operation of the IPR system. The BRP stated,

[10]For a list of forms, please see ADEQ's website "Water Quality Division: Safe Drinking Water: Monitoring and Reporting Forms and Guidance," available at https://www.azdeq.gov/environ/water/dw/monitoringandreporting.html.

> [W]ithout a state-recognized and approved training and certification program for operation of reclaimed water distribution systems, there is a risk to the entire water reuse industry in Arizona should there be an operator error in any one system that leads or directly contributes to harm or perception of harm to public health or the environment. Legal or press media scrutiny of such an error could result in public distrust and fear that operators of reclaimed water distribution systems are not qualified to do so (even though they very well may be).

In other words, getting the first IPR system right is critical to building public confidence and to setting a foundation for future IPR systems. State certification ensures for the public that certain levels of training have been completed prior to system operation, a measure of confidence to support IPR systems.

e. Maricopa County Environmental Health Code Regulations

The Maricopa County Environmental Services Department (MCESD) oversees many aspects of drinking water and incorporates ADEQ and ADWR rules and regulations. MCESD oversight includes construction and modification of drinking water, wastewater, reclaimed water facilities and systems, as well as drinking water quality. MCESD approval is required for any change to a water, wastewater, or reclaimed water facility or for any change that affects the source water supply of a PWS, if that change affects capacity, quality, flow, location, or operational performance. County regulations also require a permit for water and wastewater systems operated or maintained within the county. Finally, they also prohibit the discharge of contaminated or polluted material into any water well or other well where that material may or will penetrate the underlying water-bearing strata or pollute or contaminate groundwater.

3. *Overarching Obstacles to Implementing Indirect Potable Reuse*

Interviewees cited several overarching obstacles to implementing IPR in Arizona, ranging from the practical difficulties of implementing a new and complex program to the hostile rulemaking environment. This section details some of these difficulties.

a. Regulatory Inertia and Funding Gaps

Even if a municipality is highly motivated to implement IPR, there are still many practical obstacles. As one interviewee pointed out, wastewater treatment has been the same for decades: treating the water and dumping it into wetlands, the ocean, and other waterbodies. Implementing a new system that requires significant oversight, and changing the mentality about wastewater and its uses, will require a lot of investment, both monetary for new treatment technologies and personnel for training and education. In Arizona, as in many states, the budget reality is a serious obstacle. Interviewees commented that state agencies in Arizona are underfunded and understaffed, translating into lackluster support for new, innovative technologies and or improving and streamlining existing management regulatory systems and processes. One interviewee commented that agencies have the same or more work with fewer resources.

Interestingly, one interviewee observed an unintended consequence of smaller agency budgets: As a result of being underfunded and needing to make up for funding gaps, Arizona agencies are shifting toward user fees or charging users to cover costs. This fee-for-service mentality, driven by the need to cover budget deficits, creates an incentive for an agency to retain

maximum authority over its programs and jurisdiction but simultaneously decreases the likelihood of relinquishing some authority in favor of a streamlined permitting process for IPR. Other interviewees expressed dismay at the low resources devoted to and lack of expertise in IPR and establishing a policy for IPR. Admittedly, developing an IPR policy is complex, time-consuming, and resource-intensive, and it creates an extra workload for overtasked state agencies.

b. Arizona Executive Order 2015-01

Executive Order 2015-01 plays an important role when considering how to move toward a statewide policy on IPR and a streamlined permitting process. Signed by Governor Ducey on January 1, 2015, this Order effectively prohibits all state agencies from making new rules through December 31, 2015. Exceptions apply for rules that "fulfill an objective related to job creation, economic development, or economic expansion," to reduce or ameliorate a regulatory burden while still achieving the same regulatory objective, or to "prevent a significant threat to public health, peace, or safety" (Az. Exec. Order 2015-01). Under the Order, each agency is required evaluate its rules and notify the Governor's office of recommendations for which rules could be amended or repealed. As one interviewee summarized, the current environment for new rulemaking in state agencies is very hostile.

c. Information Gaps

A few interviewees cited information gaps as an obstacle to implementing IPR. For example, data on different treatment processes and their effectiveness at removing contaminants are unavailable, as is information about ancillary benefits that a treatment process may have on non-targeted contaminants. More information about de facto reuse over the long-term is needed, such as the health impacts of long-term use. Information about the health impacts would also help public education efforts.

d. Public Acceptance

Public acceptance and support are critical prior to implementing any IPR system. Federal policies or guidance are essential because EPA brings significant resources and scientific and technical information that states could leverage in designing their own IPR rules and regulations. Some interviewees suggested that IPR could be driven by one of the EPA regions, but others noted that states interested in IPR are not located in a single region but rather are generally spread over the western United States.

Box 1. Roadmap to Gaining Public Acceptance for IPR

1. Build trust through outreach, transparency, and public participation
2. Develop and adhere to input structure and timeline for decisions
3. Establish a compelling case for capital investment in IPR
4. Identify experts whom the public trusts
5. Work with community leaders to communicate benefits of IPR to the public.

Achieving public acceptance requires extensive outreach and education efforts. Although no health risks have been reported to date from either de facto reuse, IPR, or DPR systems, long-term health studies—especially those examining risks over generations—do not exist. Implementing IPR systems unquestionably warrants caution. Ultimately, to achieve and maintain public confidence, IPR systems will require long-term and vigilant monitoring. Both showing how technologies can speed up the natural filtration of the water cycle and promoting transparency can help overcome resistance.

Recommendations for an Indirect Potable Reuse Framework in Arizona

Potable reuse in Arizona and across the United States has been occurring for decades, although typically it has been inadvertent and unintentional. Demand for potable water supplies increases with population growth, yet those supplies are becoming strained from climatic changes and decades of over-drafting (in the case of groundwater). Intentional potable reuse—both indirect and direct—is an important strategy to meeting this demand. Public acceptance will inevitably remain a hurdle, but dire circumstances are often enough to sway opinion, as in Texas. Based on the obstacles identified above, this section provides recommendations to overcome those obstacles.

1. Requisite Factors for Indirect Potable Reuse

The existing potable reuse systems in the United States and around the world are driven by a simple reality: the lack of alternative water supplies, either because existing sources are already developed and allocated or because climatic conditions make supplies unreliable or inconsistent. As one interviewee commented, the city of Big Spring, Texas, simply ran out of water and had no choice. The physical reality was enough to overcome public fears and hesitation. Other factors that make IPR appealing are cost-effectiveness and sustainability. Treated wastewater as an alternative water source has many benefits, but those benefits are useless if the water is too expensive for ratepayers. The source of potable reuse—wastewater—must be sustainable and constant. IPR systems will be most successful in stable or growing cities with a constant or increasing stream of effluent; IPR systems are not suitable for an unstable or shrinking city. Effluent must be constant, even in light of water efficiency ordinances or improvements.

2. Recommendations

This section focuses on recommendations to IPR systems in Arizona and in Maricopa County. It begins with general design principles and then identifies legal recommendations and institutional recommendations.

a. Overarching Regulatory Principles

In conducting research and interviewing experts, two design principles became clear: First, any rules and regulations, or even statewide guidance, for IPR must accommodate individual, case-by-case circumstances for IPR systems. For example, research and experience have shown that the recharged water quality needs to closely match the receiving groundwater quality, otherwise treatment costs and clogged injection wells become problematic. In addition, the unique geological characteristics and the specific aquifer characteristics must also be considered and accounted for in any rule or regulation.

To solve this problem, some interviewees emphasized the preference for performance standards rather than specific technology standards. From a practical level, they noted that the technological landscape changes and evolves so rapidly that specifying particular technologies could lead to using outdated equipment. Combining performance standards, such as specific contaminant levels, with regular monitoring and reporting and some technological standards for certain treatment processes (such as membranes, UV, and disinfection systems) would allow IPR operators to customize operations with different technologies.

Box 2. Legal and regulatory considerations for an IPR framework (EPA 2012)

Goals
Purpose and/or goal statement
Definitions
Scope and applicability
Exclusions and prohibitions
Variances
Financial assistance
Design
Define or refine control and access to reclaimed water
Treatment technology requirements
Criteria or standards for design, siting, and construction
Construction requirements
Access control and use area requirements
Operation
Operations and maintenance
Operational flow requirements
Permitting requirements
Monitoring
Monitoring requirements
Record keeping
Contingency plan
Reporting
Reporting Frequency
Point-of-compliance for reporting
Public Notice
Education and notification
Stakeholder participation
Water Quality
Reclaimed water standards Management of pollutants from significant industrial users as source water protection
Legal Relationship
Relationship to other rules
Relationship to stakeholders
Relationship to regulations or guidelines for uses of other non-conventional water sources

Second, IPR rules and regulations should also be forward-thinking and potentially serve as a bridge to DPR. Designing rules and regulations with the flexibility to transition into DPR would reduce the need for revisiting regulations, if and when DPR becomes a viable and palatable option.

b. Recommendations for a statewide IPR Framework in Arizona

To develop a legal and regulatory framework for IPR, a state must consider myriad factors (Box 2). Beyond developing guidance, rulemaking will ultimately be necessary to ensure any IPR system meets the required elements. The most important elements include the definition of IPR, the treatment processes or standards, the environmental barrier (addressing effectiveness and longevity), monitoring and reporting requirements, assessing health risks, and overlapping jurisdiction (Crook 2014).

Definition of IPR. Both the 2010 White Paper and interviewees emphasized the need to develop a consistent definition of IPR as the starting point of any framework. The White Paper defined IPR as "the injection of advanced treated reclaimed water into the saturated zone of a potable water source aquifer" (BRP 2010). This definition includes the *intentional* use of treated wastewater and bypasses the traditional SAT process. However, it does not explicitly capture the idea of a close-coupling between the recharge and recovery wells. An IPR framework should define at the outset the critical elements of IPR, including the intentionality and the close coupling of recharge and recovery. A more significant change would update the existing classes of reclaimed water to include a specific potable reuse class or even defining potable reuse as a beneficial use.

Water Quality Standards. An IPR framework should address the water quality standards of the recharged and recovered water but also consider the original source. Arizona's SWAP program should include treated effluent as a drinking water source, and a survey of discharges into the sewage system could be conducted to help identify potential contributions of dangerous contaminants into the wastewater flow. A collection-system monitoring program may also help protect the quality of the source water.

At the WWTP, federal and state standards apply for treated wastewater that will eventually become recharged water. As one interviewee noted, the water quality of the recharged water is very important and should closely match the constituents in the water of the receiving aquifer. If

not, the difference in water quality could lead to dissolved metals or mineralized waters that can have negative effects to the environment and potable use. This interviewee said experience demonstrated that better water quality and more similar water quality results in less clogged wells, although matching water quality requires a case-by-case approach.

One potential solution to address water quality standards of reclaimed water is to treat the recharged water to drinking water standards. This high-level treatment would help reconcile the differences between CWA and SDWA-derived standards by defaulting recharged water treatment to the higher potable water standards. It is unclear whether existing WWTP have the capacity to consistently achieve drinking water standards or what the cost of such treatment would be, but recharging wastewater as potable drinking water would ensure that drinking water quality standards are met and ensure public health and safety. Treating wastewater to the highest standards could potentially also shuffle IPR systems under existing permitting and use regulations without having to implement new regulations.

Environmental Barrier. A statewide IPR framework must also address the role of the environmental barrier. In the case of closely coupled IPR, the environmental barrier is the aquifer. Arizona could adopt a strategy similar to California, which requires a minimum residence time (two months). However, Arizona would have to define how to determine storage time or identify what technologies or techniques to establish storage time, such as dye testing, are acceptable. Arizona could also consider pre-recharge or post-recovery treatment to provide the equivalent additional treatment that an environmental barrier such as a wetland or percolation would otherwise provide. Additional technical work and studies are needed to address and determine if aquifers are adequate environmental barriers.

The state could also simply set standards for recharged IPR that are more stringent than federal CWA discharge standards and that must be achieved prior to recharge. Such state-level standards would bridge the quality gap between CWA and SDWA standards. Stringent water quality recharge standards would provide flexibility to meet water demands as needed rather than having to wait a prescribed amount of time. Overall the determination may be made on a case-by-case basis.

Biologically Active Aquifers. A handful of interviewees expressed concern about the potential of treated wastewaters to transform aquifers into biologically active aquifers, namely by injecting water with *Giardia lamblia* or *Cryptosporidium*. The latter is extremely resistant to standard disinfection techniques, such as chlorination. Historically, aquifers were not considered biologically active. However, EPA has recognized that fecal contamination can reach aquifers from failed septic systems, leaking sewer lines, and through soil and cracks in the ground. By recharging with treated wastewater, the potential for aquifers to become biologically active increases. Because many users withdraw from the same aquifer, including small-scale, domestic users without the capacity to treat these pathogens, IPR systems must address the potential for biologically active aquifers. This could include different treatment practices at the WWTP or additional treatment at the recovery well. In a broader context, developing an IPR framework could also be an opportunity to revisit how Arizona should implement holistic management of aquifers, which are subject to many activities including injection and recovery activities related to remediation, surface water, reclaimed water, drinking water, mining, and effluent disposal.

For pathogens such as *Cryptosporidium* and *Giardia lamblia*, Arizona could consider California's approach of requiring log-reductions and crediting some reductions with residence time in the aquifer.

Disinfection Byproducts. When chlorine is added to water for disinfection, the byproducts may contaminate the water. Disinfection byproducts are not currently measured or managed in reclaimed water distribution systems, but they are potentially higher in concentration than in drinking water from traditional sources. An IPR framework could require the minimal amount of chlorine necessary to be used, reduce the age of the wastewater, or reduce the total amount of organics in the source water. Water that has reduced total organic carbon content and has a shorter residence time in aquifers is more likely to have fewer disinfection byproducts than water with an extended residence time.

Groundwater Under the Direct Influence of Surface Water. Arizona requires every surface water system to filter and disinfect water prior to distributing it as drinking water. In addition, any public water supply plant (PWS) that uses Groundwater Under the Direct Influence of Surface Water (GUDI), must treat that water as if it were surface water (AAC R-18-4-212). Thus, those PWS must filter and disinfect GUDI (ADEQ 1999). A potential regulatory option is to classify recharged effluent as GUDI and require recovered water to meet the same water quality standards and treat for pathogens prior to recharge. Unlike a DPR system, however, a closely coupled IPR system would still inject the treated water into the aquifer rather than using it immediately.

One important exemption is worth noting: A facility using surface water from the Colorado River, which contains treated wastewater and is delivered through the Central Arizona Project (CAP), is not required to obtain an APP for underground storage and recovery projects (ARS § 45-250(B)(13)). The facility is still required to obtain an underground storage facility permit, for which ADEQ must determine that the location of the facility will not cause unreasonable harm from the migration of a contaminant plume, the migration of a poor quality groundwater, or from pollutants being leached to the groundwater table (ARS § 45-811.01). The CAP operates six recharge projects, all of which use infiltration basins where raw surface water only undergoes SAT before reaching the aquifer (CAP 2013). If future CAP recharge projects directly inject Colorado River water into the aquifer, they would be similar to IPR projects and will likely invoke concerns similar to closely coupled IPR. (Gary and Scottsdale are already doing it.)

Interference with Existing Uses. Although the Arizona Supreme Court recognized that an entity that produces treated wastewater can use that water as it sees fit, a problem may still arise with respect to protecting or reserving the volume of recharged water for that entity from other users within the same aquifer. An entity's recharged treated effluent, while stored in an aquifer, must be protected in a way that others will not withdraw or otherwise undermine this resource. This problem is likely common to a handful of water banking and storage programs in Arizona and should be considered in the context of IPR.

Another important existing use is the treated wastewater delivered for non-potable uses, which for many uses is contractually obligated delivery. Cities and end-users such as golf courses, turf irrigation, and landscapers have invested significant amounts of money to acquire treated wastewater and may not be willing to let contracts expire or otherwise relinquish use to augment the potable drinking water supply.

Monitoring and Reporting. Although monitoring and reporting are routine requirements for WWTPs and DWTPs, IPR will require particularly stringent and real-time monitoring because of the nature of the source water. IPR treatment must be able to produce water that consistently and continually meets the applicable water quality standards. An IPR framework should consider how this monitoring and reporting can be combined with existing monitoring and reporting requirements and how the reporting format can be streamlined across all permits and agencies. For example, data and results could be housed in a central database that all agencies could access.

The framework will also have to consider the differences between where the points-of-compliance are located. For example, a closely coupled IPR system may necessitate a POC located at the recharge wellhead to address biological regrowth that may have occurred during the time and distance it takes to deliver treated wastewater to the wellhead. Although IPR may add another POC, the framework should identify the most problematic contaminants and try to minimize additional testing requirements. For example, an IPR system could employ tiered or strategic testing such that subsequent POCs would test only for new contaminants (resulting from adding disinfectants or from residence time), rather than testing for all contaminants at each point along the flow of treated wastewater.

Operational and Certification Requirements. An IPR Framework should identify the basic training and certification requirements for operators of IPR systems and potentially develop a single set of requirements for both the recharge and recovery processes. The technological ability to treat wastewater has been demonstrated, but the technology is vastly different and more complex than the technology and equipment in use for traditional drinking water treatment. Currently, ADEQ issues operator certifications. Recharge operations require a wastewater certification while recovery requires a water certification. Thus, currently closely coupled IPR systems would require dual certification.

Engineering Report. A few interviewees supported the idea of requiring an Engineering Report for all aspects of an IPR system, much like the report required in California and Florida. An engineering report is already required for one specific aspect, obtaining an APP to recharge treated wastewater. An IPR Engineering Report would the project applicant to thoroughly consider all components and processes of the IPR system, including contingency plans and emergency responses. A report would get regulators involved early in the process of system development. Apart from the substantive content, an Engineering Report would notify all agencies involved in the approval, permitting, and construction process, to help ensure smooth implementation.

Institutional Recommendations. In addition to streamlining the permitting process, one interviewee suggested that the permitting *process*—particularly the public comment process—could be more transparent. Agency resources must also be dedicated to the effort to develop an IPR framework, which is likely to involve multi-year stakeholder efforts. These efforts tend to require many resources, political and agency commitment, and long-term support.

Conclusion

Indirect potable reuse offers significant benefits for securing water supplies against drought and shortages and for maximizing the return on investment in water treatment and delivery infrastructure. Existing potable water supplies have relied on traditional water sources since nearly the founding of the United States, and de facto potable reuse has long occurred under the radar and outside the realm of public awareness. Implementing intentional, closely coupled IPR systems

requires overcoming the decades of inertia from relying on traditional water supplies and gaining political and public support and acceptance.

Although this white paper focuses on obstacles specific to Arizona, similar obstacles are likely to be encountered in other states. IPR presents a unique and novel challenge for water managers and water providers. It bridges the water cycle with wastewater, reclaimed water, and drinking water into a single system that raises issues for water resources management, planning, engineering design, operations, maintenance, and regulatory and oversight. Successful IPR requires people who are fluent in all these different aspects to understand the complexities of IPR systems. Formalizing a uniform, statewide framework for IPR is a long-term goal, but small steps—working with local and state regulators, implementing pilot projects, and gathering information and data about how these projects operate—are nevertheless critical. Water providers can build relationships and maintain communication channels with regulators, as well as provide feedback about the practical difficulties between regulatory standards and implementation realities.

Five years after the Blue Ribbon Panel report, Arizona has the capacity to develop a robust and practical framework for IPR. The gap between water demand and water supply across the state has driven innovative and pioneering water management strategies, and IPR represents the next iteration of these strategies to augment the potable water supply.

Acknowledgments

I am grateful to Gary Gin and Cliff O'Neal for the opportunity to work on this project, which helped illuminate the gaps between laws and policies as written and as implemented on the ground. I thank the interviewees who generously gave their time and shared their insights into IPR in Arizona: Guy Carpenter, Andrew Craddock, Heather Finden, Gary Gin, Charles Graf, Randy Gottler, Susan Kinkade, and William Kenning, as well as Richard Obenshain for commenting on an earlier draft. Itzel Marquez helpfully explained wastewater treatment from an engineer's perspective. Finally, I am grateful to Sharon Megdal for her guidance as my advisor.

References

1. Legal References

Federal

Safe Drinking Water Act, 42 U.S.C. §§ 300f et seq.

Clean Water Act, 33 U.S.C. §§ 1251 et seq.

Arizona

Arizona Revised Statutes (ARS) §§ 45-151(A), 49-201(12), 49-223, 49-224, and 49-241 et seq.

Arizona Administrative Code (AAC) rules R18-9-101 et seq., R18-11-401 et seq., and R18-5-502 et seq.

Arizona Public Services Company v. Long, 773 P.2d 988 (Ariz. 1989).

Arizona Office of the Governor. 2015. Executive Order 2015-01. Available at http://azgovernor.gov/file/1340/download?token=dQRZQZCt.

Maricopa County Environmental Health Code: Water Supply, Chapter V, Section 1. Available at http://www.maricopa.gov/EnvSvc/AboutUs/pdf/C5S1.PDF.

California

California Code of Regulations (CCR) Title 22, §§ 60320.200 et seq.

Florida

Florida Administrative Code (FAC) rules 62-610.550, 62-610.56, and 62-610.200(27).

2. Literature References

ADEQ. 1999. Arizona Source Water Assessment Plan Final Draft (February 5 1999). Available at https://www.azdeq.gov/environ/water/dw/download/swapplan.pdf.

ADWR. 2010. Arizona Water Atlas Volume 8: Active Management Area Planning Area. April 2010. Available at http://www.azwater.gov/azdwr/StatewidePlanning/WaterAtlas/ActiveManagementAreas/documents/Volume_8_final.pdf.

_____. 2014. Arizona's Next Century: A Strategic Vision for Water Supply Sustainability. January 2014. Available at http://www.azwater.gov/AzDWR/Arizonas_Strategic_Vision/documents/ArizonaStrategicVisionforWaterResourcesSustainability.pdf.

ATSE (Australian Academy of Technological Sciences and Engineering). 2013. Drinking Water Through Recycling: The Benefits and Costs of Supplying Direct to the Distribution System. October 2013. Available at http://www.atse.org.au/Documents/Publications/Reports/Water/drinking-water-through-recycling-full-report.pdf.

Balling, Robert C., Jr., and Patricia Gober. 2007. Climate Variability and Residential Water Use in the City of Phoenix, Arizona. Journal of Applied Meteorology and Climatology 46: 1130-1137. doi: 10.1175/JAM2518.1.

Bracken, Nathan S. 2012. Water Reuse in the West: State Programs and Institutional Issues. A Report Complied by the Western States Water Council. Hastings West-Northwest Journal of Environmental Law & Policy. 18: 451-529.

BRP (Arizona Blue Ribbon Panel on Water Sustainability). 2010. Final Report. Available at http://www.azwater.gov/AzDWR/waterManagement/documents/BRP_Final_Report-12-1-10.pdf.

CAP (Central Arizona Project). 2013. "Recharge Program." Last modified 2013. http://www.cap-az.com/index.php/departments/recharge-program.

Crook, James. 2010. Regulatory Aspects of Direct Potable Reuse in California. National Water Research Institute White Paper NWRI-2010-01 (April 2010). Available at http://www.nwri-usa.org/pdfs/NWRIPaperDirectPotableReuse2010.pdf.

Dellapenna, Joseph W. 2013. A Primer on Groundwater Law. Idaho Law Review 49: 265-323.

du Pisani, Petrus L. 2006. Direct reclamation of potable water at Windhoek's Goreangab reclamation plant. Desalination 188: 79-88. doi:10.1016/j.desal.2005.04.104.

EPA (U.S. Environmental Protection Agency). 1980. Wastewater in Receiving Waters at Water Supply Abstraction Points. EPA-60012-80044.

_____. 2004. Guidelines for Water Reuse. EPA/625/R-04/108 (September 2004). Available at http://water.epa.gov/aboutow/owm/upload/Water-Reuse-Guidelines-625r04108.pdf.

_____. 2004. Understanding the Safe Drinking Water Act. 816-F-04-030 (June 2004). Available at http://water.epa.gov/lawsregs/guidance/sdwa/upload/2009_08_28_sdwa_fs_30ann_sdwa_web.pdf.

_____. 2012a. 2012 Guidelines for Water Reuse. EPA/600/R-12/618 (September 2012). Available at http://nepis.epa.gov/Adobe/PDF/P100FS7K.pdf.

_____. 2012b. "Source Water Assessments." Last modified March 6, 2012. http://water.epa.gov/infrastructure/drinkingwater/sourcewater/protection/sourcewaterassessments.cfm.

_____. 2013a. "Secondary Drinking Water Regulations: Guidance for Nuisance Chemicals." Last modified May 31, 2013. http://water.epa.gov/drink/contaminants/secondarystandards.cfm#one.

_____. 2013b. "Basic Information about Pathogens and Indicators in Drinking Water." Last modified December 13, 2013. http://water.epa.gov/drink/contaminants/basicinformation/pathogens.cfm.

_____. 2014. "Pretreatment." Last modified September 9, 2014. http://water.epa.gov/polwaste/npdes/pretreatment/

EPA OIG (Office of the Inspector General). 2005. Source Water Assessment and Protection Programs Show Initial Promise, but Obstacles Remain. Report No. 2005-P-00013 (March 28, 2005). Available at http://water.epa.gov/infrastructure/drinkingwater/sourcewater/protection/upload/20050328-2005-P-00013.pdf.

EPA Office of Wastewater Management. 2011. Introduction to the National Pretreatment Program. EPA-833-B-11-001 (June 2011). Available at http://water.epa.gov/polwaste/npdes/pretreatment/upload/pretreatment_program_intro_2011.pdf.

Finley, Bruce. 2014. Colorado weighs taking "waste" out of wastewater to fix shortfall. *The Denver Post* (November 23, 2014). Available at

http://www.denverpost.com/environment/ci_26994785/colorado-weighs-taking-waste-out-wastewater-fix-shortfall.

Gale, Sarah Fister. 2013. Battling Water Scarcity: Direct Potable Reuse Poised as Future of Water Recycling. WaterWorld 29(9). Available at http://www.waterworld.com/articles/print/volume-29/issue-9/editorial-features/battling-water-scarcity.html.

GAO (U.S. Government Accountability Office). 2014. Freshwater: Supply Concerns Continue, and Uncertainties Complicate Planning. GAO-14-430 (May 22, 2014). Available at http://www.gao.gov/products/GAO-14-430.

Grant, Stanley B., Jean-Daniel Saphores, David L. Feldman, Andrew J. Hamilton, Tim D. Fletcher, Perran L. M. Cook, Michael Stewardson, Brett F. Sanders, Lisa A. Levin, Richard F. Ambrose, Ana Deletic, Rebekah Brown, Sunny C. Jiang, Diego Rosso, William J. Cooper, and Ivan Marusic. 2012. Taking the "Waste" Out of "Wastewater" for Human Water Security and Ecosystem Sustainability. Science (August 10, 2012). 337(6095): 681-686. doi:10.1126/science.1216852.

Martin, Laura. 2013. Direct potable reuse vs. indirect: Weighing the pros and cons. Wateronline.com (November 4, 2013). Avaliable at http://www.wateronline.com/doc/direct-potable-reuse-vs-indirect-weighing-the-pros-and-cons-0001.

Martin, Laura. 2014. Texas leads the way with first direct potable reuse facilities in the U.S. Water Online (September 16, 2014). Available at http://www.wateronline.com/doc/texas-leads-the-way-with-first-direct-potable-reuse-facilities-in-u-s-0001.

Maupin, Molly A., Joan F. Kenny, Susan S. Hutson, John K. Lovelace, Nancy L. Barber, and Kristin S. Linsey. 2014. Estimated use of water in the United States in 2010. U.S. Geological Survey Circular 1405, 56 p. doi: 10.3133/cir1405.

Middel, Ariane, Ray Quay, and David D. White. 2013. Water reuse in central Arizona. Decision Center for a Desert City Technical Report 13-01. Tempe, AZ: Arizona State University, 32 p.

NRC (National Research Council). 2012. *Water Reuse: Potential for Expanding the Nation's Water Supply through Reuse of Municipal Wastewater*. Washington, D.C.: National Academies Press.

_____. 1998. *Issues in Potable Reuse: The Viability of Augmenting Drinking Water Supplies with Reclaimed Water*. National Academies Press: Washington, D.C.

OCWD. 2014. A History of the Orange County Water District. Available at http://www.ocwd.com/Portals/0/About/HistoricalInformation/A%20History%20of%20Orange%20County%20Water%20District.pdf.

Reisner, Mark. 1993. *Cadillac Desert*. Penguin Books: New York, NY.

Rice, Jacelyn, Amber Wutich, and Paul Westerhoff. 2013. Assessment of De Facto Wastewater Reuse across the U.S.: Trends between 1980 and 2008. Environ. Sci. Technol. 47(19): 11099–11105. doi: 10.1021/es402792s.

Robinson, K.G., C.H. Robinson, and S.A. Hawkins. 2005. Assessment of public perception regarding wastewater reuse. Water Science and Technology: Water Supply 5(1): 59-65. http://www.environmental-expert.com/Files%5C5302%5Carticles%5C9786%5CAssessmentofpublicperceptionregarding.pdf.

Rock, Channah, Frederic I. Solop, and Daniel Gerrity. 2012a. Survey of statewide public perceptions regarding water reuse in Arizona. Journal of Water Supply: Research and Technology—AQUA 61(8): 506–517. doi:10.2166/aqua.2012.070.

Rock, Channah, Jean E. McLain, and Daniel Gerrity. 2012b. Water Recycling FAQs. University of Arizona Cooperative Extension Publication AZ1568 (May 2012). Available at http://extension.arizona.edu/sites/extension.arizona.edu/files/pubs/az1568.pdf.

Rodriguez, Clemencia, Paul Van Buynder, Richard Lugg, Palenque Blair, Brian Devine, Angus Cook, and Philip Weinstein. 2009. Indirect potable reuse: A sustainable water supply alternative. Int. J. Environ. Res. Public Health 6: 1174-1209. doi: 10.3390/ijerph6031174.

Schempp, Adam. 2010. Western Water in the 21st Century: Policies and Programs That Stretch Supplies in A Prior Appropriation World. Environmental Law Reporter News & Analysis 40: 10394-10418.

Stein, Jay F., James C. Brockmann, Cynthia F. Covell, and John C. Peck. 2011. Water Use and Reuse: The New Hydrologic Cycle. Rocky Mountain Mineral Law Institute 57: 29-1—29-27.

WRF (WateReuse Foundation). 2004. *Best practices for developing indirect potable reuse projects: Phase I Report.* WRF-01-004. 97 p.

Appendix A: List of Interviewees

Below is a list of experts interviewed for this White Paper. All interviews were conducted in person at various locations in Phoenix, Arizona.

Interviewee	Position	Date of Interview
Guy Carpenter	Water Reuse Practice Director Carollo Engineers	January 20, 2015
Andrew Craddock	Manager, Assured Water Supply and Recharge Programs Arizona Department of Water Resources	January 30, 2015
Heather Finden	Water Services Project Coordinator City of Phoenix	January 20, 2015
Gary Gin	Hydrologist Water Services Division, City of Phoenix	February 9, 2015
Charles Graf	Senior Hydrologist, Water Quality Division Arizona Department of Environmental Quality	February 9, 2015
Randy Gottler	Deputy Water Services Director City of Phoenix	January 20, 2015
Susan Kinkade	Water Services City of Phoenix	January 20, 2015
William Kenning	Engineer, Treatment Program Maricopa County Environmental Services Division	January 30, 2015

Appendix B: Interview Questions

Interviewees were provided with the document prior to the interview.

A Regulatory Framework for
Indirect Potable Reuse in Arizona: Interview Questions

Thank you very much for participating in this interview. All interview responses will be kept confidential and reported anonymously, unless permission is granted prior to any public dissemination of or use in the final report. If you have any questions, please feel free to contact Yee Huang (huanglingyee@email.arizona.edu), Gary Gin (gary.gin@phoenix.gov), or Cliff Neal (cliff.neal@phoenix.gov).

1. We have provided a copy of "Indirect Potable Reuse within Aquifers," White Paper #10 from the 2010 Blue Ribbon Panel on Water Sustainability Report. Have you read this document? If so, do you agree or disagree with the need to develop a statewide, unified policy on IPR?
2. Do you have any other thoughts or reactions to the paper?
3. How would you clarify existing regulations to allow recharged reclaimed water to be source water for potable purposes?
4. Arizona has the Aquifer Protection Program (ADEQ), Underground Storage Facility Permit (ADWR), and Safe Drinking Water Program (ADEQ and county agencies). Should these regulatory programs to be unified or streamlined for IPR purposes? If so, how? Please explain.
5. What are the legal and regulatory inconsistencies or ambiguities to implementing indirect potable reuse?
    a. Federal level?
    b. State level?
    c. County level?
6. What changes would you propose to remove these inconsistencies and ambiguities?
7. What are the some of the other obstacles to implementing indirect potable reuse?
    a. Engineering or technological, such as treatment versus levels of detection?
    b. Capital or other resources?
    c. Public Acceptance?
    d. Others, such as long-term health risks?
8. If the obstacles above were resolved, what do you think it would take for regulatory agencies to support IPR?
9. Do you know of any good case studies for indirect potable reuse? Do you know of any model regulations?
10. Is there anyone you'd recommend speaking with?
11. Are there any particular resources that you'd recommend?