Arid Inland Community Survey on Water Knowledge, Trust, and Potable Reuse. I: Description of Findings

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Abstract: Planned potable water reuse has the potential to improve the sustainability and reliability of water supplies, but implementation has faced public acceptance challenges. Although the US Department of the Interior has predicted that hot spots of conflict over water are highly likely in the arid inland western US, significant knowledge gaps exist regarding public perceptions of potable reuse and understanding of water-related topics in this context. This study aims to fill these gaps with a large-scale ($n = 1{,}831$) survey in Albuquerque, New Mexico, to determine public acceptance of two types of potable reuse and collect data on the population's climate and water-related knowledge, water use at home, level of trust in institutions, and demographics. The survey was developed and refined through a series of community focus groups and debriefing sessions, and the response rate was 46%. This population had higher overall levels of acceptance of potable reuse and awareness of water scarcity-related issues compared with coastal populations from other studies, with implications for design of education and outreach programming. **DOI: 10.1061/(ASCE)WR.1943-5452.0001218.**

Author keywords: Water reuse; Water recycling; Water scarcity; Public perception; Trust; Public education and outreach.

Introduction

Background

Globally, one of the most critical planning challenges of the coming decades is ensuring the availability of clean and reliable water supplies. Indeed, stressed water supplies are a reality in the US Southwest, where climate change is expected to cause more frequent drought, more variable rainfall, and less reliable water supplies (Brookshire et al. 2013; Miller et al. 2012). A US Department of Interior (DoI) report predicted "hot spots" of conflict over water in the United States by 2025 (US Bureau of Reclamation 2005), and communities within these hot spots must consider available supply- and demand-side options to create sustainable and reliable water supplies (Ghassemi et al. 2017; Grant et al. 2012; Hering et al. 2013; Hurlimann et al. 2009; Porse et al. 2017). Scholars have developed tools to help water planners decide how best to develop their options given future climate and demographic uncertainties and complexities (Ray et al. 2009, 2011) and the evolving landscape of public acceptance and adoption of water reuse projects (Kandiah et al. 2016).

Indirect and direct potable water reuse (IPR and DPR, respectively) are two supply-side options that hold promise for improving the sustainability and reliability of potable water supplies by generating high-quality drinking water from wastewater and significantly increasing "water productivity" (Grant et al. 2012). Typically, in IPR, wastewater treatment plant (WWTP) effluent is highly treated in an advanced treatment facility and directed to an environmental buffer, such as a lake or aquifer, prior to withdrawal and treatment at a drinking water treatment plant (DWTP). DPR is the same except that no environmental buffer is included, and the advanced treated water is either directed to the distribution system or combined with traditional water sources and treated at the DWTP (Leverenz et al. 2011; Tchobanoglous et al. 2011).

IPR and DPR are increasingly being considered in communities with exceptional water scarcity (Scruggs and Thomson 2017). Although potable reuse technologies are currently available to purify treated wastewater to drinking water standards, the practice has faced challenges associated with culture (Loáiciga 2014) and public acceptance (Dolnicar et al. 2010; Hurlimann and Dolnicar 2010), and public support for potable reuse projects is as important to project success as the technologies that make water reuse possible (Macpherson and Snyder 2013). Thus, much research has centered on trying to understand public attitudes toward potable water reuse and the reasons for past projects' success or failure.

Previous Research on Public Perception of Potable Water Reuse

Negative public perceptions of potable reuse have led to cancellation or tabling of numerous potable reuse projects, and researchers believe the negative perceptions are influenced by a variety of factors. A lack of knowledge or misperceptions about the water cycle and/or treatment technologies is often emphasized (Macpherson and Snyder 2013; Wegner-Gwidt 1991). For example, survey results have shown that although residents may be aware of water shortages, they are relatively unaware of the urban water cycle, including the source of drinking water and what happens to it after use (Gu et al. 2015). Misinformation dissemination by reuse project

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opponents prior to official community education and outreach programming (Hurlimann and Dolnicar 2010) and a failure by project proponents to effectively engage with the public about water resource options (Hurlimann and Dolnicar 2010; Stenekes et al. 2006) have also been named as reasons for project failure.

Some scholars have focused on individual disgust at drinking treated wastewater as the explanation for a reuse project's success or failure (Parkinson 2008; Schmidt 2008), and others have stressed the importance of local context (Friedler and Lahav 2006; Hartley 2006; Khan and Gerrard 2006; Ormerod and Scott 2012; Russell and Hampton 2006). Contextual differences such as climate, location, and history of water scarcity may impact the level of acceptance of reuse (Garcia-Cuerva et al. 2016). Ormerod and Scott (2012) demonstrated that "potable reuse is a politicized issue, where expressed concerns reflect social values more complicated than simple revulsion," and that individual perceptions are shaped by local context, which can include public trust in the authorities and institutions initiating discussions about water reuse and how public outreach and communication is conducted.

No matter how well designed the educational information provided about a potential reuse project, uncertainty can be introduced if the public does not trust the institution, entity, or individual providing the information. Previous studies have suggested that there is generally a low level of trust in government officials, politicians, and the media, and a higher level of trust in researchers, public health professionals, and water utility representatives (Fielding et al. 2015; Hartley 2006; Millan et al. 2015; Ormerod and Scott 2012). Trust is built over time, and those planning water reuse projects should work to ensure that the information about a project that is distributed to the public comes from entities the public trusts (Ormerod and Scott 2012).

Bottom-up or collaborative processes have been recommended for introducing controversial water reuse projects because they build public confidence and trust (Hartley 2006; Hering et al. 2013). Hartley (2006) specified a framework for "public outreach, education, participation, and planning" for water reuse projects. Documented experiences reinforce this framework in creating "community-based, consensus-driven solutions" (Ingram et al. 2006) and in failure to gain public trust (Hurlimann and Dolnicar 2010). Excellent communication with the public on potable reuse issues is crucial, and vocabulary and image choices influence public perceptions and acceptance (Macpherson and Slovic 2011). Another important influence on acceptance of IPR and DPR is prior knowledge of unplanned, or de facto, potable reuse (Macpherson and Snyder 2013).

Although IPR also faces public opposition, it tends to have a higher level of public acceptance compared with DPR because of perceived purification by natural processes, which serves to distance water from its history as wastewater (Millan et al. 2015; Rodriguez et al. 2009). However, IPR is not always feasible due to lack of a suitable environmental buffer (Leverenz et al. 2011), making it important to understand public knowledge, perceptions, and attitudes related to both potable reuse options.

Although the body of literature related to public acceptance of water reuse is growing, most previous research has been conducted in large coastal US cities or Australia, and significant knowledge gaps exist regarding arid inland communities' perceptions of potable reuse and understanding of topics such as water scarcity and climate change. Research on potable reuse in the arid inland context is important because many communities that are candidates for potable reuse in the United States are scattered throughout the inland Southwest (US Bureau of Reclamation 2005). Experts have suggested that numerous communities and contexts be studied for a broader understanding of water management alternatives (National Research Council 2012), and recent research has suggested that recommendations based on experiences with water reuse in large coastal communities do not necessarily apply in smaller inland communities. For example, Scruggs and Thomson (2017) concluded that technological, legal, and economic challenges associated with DPR in arid inland communities may be different from those in large coastal communities, and Scruggs et al. (2019) found that the public education, outreach, and engagement programs used to gain public acceptance of DPR in several small- and medium-sized arid inland communities were less extensive than what experience in larger coastal communities suggests is required.

Objectives of This Research

The current study aims to help fill the knowledge gaps on arid inland communities' perceptions of potable reuse and understanding of topics such as water scarcity and climate change by presenting the findings from the first large public survey known to the authors on public acceptance of planned potable reuse in an arid inland area. It also presents a rigorous method of survey design and administration that has not yet been used in the water reuse survey literature. Albuquerque/Bernalillo County in New Mexico is an inland community with significant potential for water conflict (US Bureau of Reclamation 2005). The Albuquerque-Bernalillo County Water Utility Authority (ABCWUA) has included potential implementation of IPR and DPR in its 100-year water plan (Albuquerque Bernalillo County Water Utility Authority 2016), but discussions and debates surrounding potable reuse have not yet entered mainstream public discourse. Albuquerque/Bernalillo County was used as a case study, collaborating with the ABCWUA and using water utility account holders as the sample population.

Based on anecdotal information from ABCWUA staff about high levels of public acceptance of potable reuse, and the fact that the local physical landscape very much reflects the reality that residents live in a dry desert environment, the authors hypothesized that Albuquerque and Bernalillo County residents would have heightened knowledge and awareness of water scarcity–related issues and would be more willing to accept potable water reuse than their counterparts in large coastal US communities. A large community survey was designed to test this hypothesis. The results of this study will be useful to ABCWUA as well as water planners, city officials, and policy actors in other arid inland areas who are interested in the feasibility of potable water reuse for their communities or in designing public outreach strategies related to potable reuse.

The research findings are presented in two parts, as described in two separate papers. Part I present the basic results from the survey for comparison with the results of numerous similar surveys that have been performed in other communities and contexts. Part II focuses on demographic and contextual factors that influence acceptance of potable water reuse in an arid inland context, with a review of previous relevant research, description of methods, and more advanced statistical analyses of the data.

Methods

The data described in this study were collected using a large-scale community survey that was sent through the mail to 4,000 account holders of the ABCWUA, the sole provider of water and wastewater services to the greater Albuquerque, New Mexico, metropolitan area, serving over 600,000 water users. The tailored design method (Dillman et al. 2014) was used to design and conduct our survey to achieve the highest possible response rate. Our methods have been described in detail elsewhere (Distler 2018), and only a summary is provided here. All research described in this paper was approved by the University of New Mexico's Institutional Review Board (IRB).

The initial survey materials were created based on previous research described in the literature. Following best practices for survey design and implementation, the preliminary steps in conducting the pretest and survey included a series of focus groups and debriefing sessions with individual members of our sample population (Dillman et al. 2014; Thacher et al. 2011). To identify attributes for inclusion and test prototypes of survey questions (Krueger and Casey 2000), eight 90-min focus groups were conducted with 7–10 participants per group at a variety of familiar and accessible locations that uniformly covered all quadrants of the community. Focus group participants were required to be ABCWUA account holders and at least 18 years of age, and they were offered a $30 gift card and refreshments as an incentive to participate.

Participants identified materials that were most useful to them, information and figures that they felt were too complicated, problems with vocabulary, content, and structure, and additional information that would be helpful for decision making. Midway through and at the conclusion of the series of focus groups, one-on-one debriefing sessions were also conducted with 12 participants who were asked to think aloud as they took the survey. These participants were recruited in the same way as described previously for the focus groups, and these individual meetings were used to determine if questions were being interpreted as intended, the time required to take the survey, and if there were any potential problems in completing the survey (Dillman et al. 2014; Thacher et al. 2011). The focus groups were held in July 2016, except for the last two, which were conducted in late October and early November of 2016. The debriefing sessions were held in August, October, and November 2016. The final survey instrument (Fig. S1) contained 26 questions, most of which pertained to water resources and water reuse, but also included nine questions related to demographics.

The sample (totaling 4,200 residential accounts) was randomly selected from the ABCWUA's customer accounts log, which contained over 180,000 residential accounts. Included in the customer accounts log were customer names and several geographic variables (i.e., address, ZIP code, census block and tract, and city quadrant). In order to preserve anonymity and track responses, customer names were deleted from the sample file, and a random 6-digit code was given to each potential respondent as a unique identifier. Using the city quadrant variable, the authors were able to ensure that the proportion of the sample in each quadrant was within ± 0.01 (1%) of the proportions in the customer accounts log. The other geographic variables, including customer addresses, were retained only until final analyses were completed. Because the authors had only physical addresses and not customers' email addresses or phone numbers, the survey was conducted by mail, with an option to complete it online using Survey Monkey.

The final draft survey instrument was pretested on a random sample of 200 ABCWUA account holders to verify the instrument, estimate the response rate for the larger survey, and test the administration procedures (Thacher et al. 2011). With information gleaned from the pretest, the survey instrument and administration process were finalized, and the survey was then sent to a random sample of 4,000 ABCWUA account holders using a system of five contacts over a period of 9 weeks (April 19 through June 19, 2017) (Dillman et al. 2014). The contact with the first survey packet also included a $2 bill because including a cash incentive can increase response rates, as discussed by Dillman et al. (2014). The survey was open to responses through September 5, 2017, and the response rate was 45.8% ($n = 1{,}831$). Only 15% of respondents elected to respond online. The mail-in responses were entered into Survey Monkey, then all Survey Monkey data were downloaded into Excel and analyzed the data using Excel and R Studio version 1.0.136, an open-source statistical software.

Results and Discussion

The survey contained questions related to six major themes: (1) level of concern for water-related issues, (2) water supplies and climate change, (3) water use at home, (4) acceptance of potable reuse and reasons for support or concern, (5) trust in institutions, and (6) demographics. The following subsections discuss the findings for Themes 1–5, with a comparison to the descriptive statistics reported from previous surveys of other populations. The demographic characteristics of the survey respondents are summarized in Table S1, and detailed findings related to demographics are discussed in Part II. The discussion of findings is followed by an examination of study limitations.

Level of Concern for Water-Related Issues

The first question in the survey was included to gauge the importance of water issues relative to other issues in the Albuquerque area. Of the eight issues respondents were asked about, three were water-related (i.e., drought and water shortage, drinking water quality, and amount paid on water bill). Respondents were asked to indicate their level of concern for each issue using a 5-point Likert-type scale. Table 1 presents the sum of the top two categories (i.e., very concerned and extremely concerned) for each issue, and the issues are listed from greatest level of concern to least.

Overall, the results showed that water issues fell in the middle of the pack relative to other community concerns. The top three issues of concern were the crime rate, quality of public education, and jobs and the local economy, with 73%, 68%, and 62%, respectively, of respondents indicating that they were "Very" or "Extremely" concerned about these issues. Respondents seemed to be slightly less concerned about water-related issues, with 47% and 46% indicating they were "Very" or "Extremely" concerned about drought and water shortage and drinking water quality, respectively.

Several of the response options were adapted from a study by Millan et al. (2015), which found that water issues ranked higher in level of concern among 1,200 southern California voters than they did among participants of the present survey. The discrepancy could be explained by several contextual factors. The Millan et al. (2015) study was conducted during a noteworthy statewide drought in California, whereas exceptional conditions were not a factor during the present survey's timeframe. It is not surprising that the present survey's respondents were more concerned about the crime rate and the quality of public education given that the 2016 Federal Bureau of Investigation (FBI) *Crime in the United States* report (US Department of Justice and Federal Bureau of Investigation 2017) showed that New Mexico has the highest

Table 1. Community issues sorted from highest to lowest level of concern

Issue and rank	Total very/extremely concerned (%)
1. Crime rate	73
2. Quality of public education	68
3. Jobs and local economy	62
4. Drought/water shortage	47
5. Drinking water quality	46
6. Amount paid in local taxes	41
7. Amount paid on water bill	36
8. Population growth	35

property crime rates per 100,000 people in the country and the second highest rate for violent crime.

Also, according to the 2018 Education Week *Quality Counts* national report (Education Week Research Center 2018), which ranks the quality of public education in the United States, New Mexico was ranked next to last. Although the comparison between populations from southern California and central New Mexico is interesting, that the authors also stress that Millan et al. (2015) did not provide a response rate for their telephone survey, making it difficult to determine how representative their respondents were of the population to detect any potential biases in the methods for data collection. Regardless, Millan et al.'s (2015) study is one of the most comprehensive to date, and it is used as a point of comparison throughout this paper.

Water Supplies and Climate Change

The authors sought to understand respondents' knowledge and beliefs about local water scarcity and water resouces. First, respondents were asked if they believed water to be a limited resource in Albuquerque. Eighty-one percent of respondents answered "Yes," 10% answered "No," and 7% answered "I don't know" (for some survey questions, the percentages reported in the results will not sum to 100% due to nonresponses.) This result aligns with the hypothesis that water customers in Albuquerque and Bernalillo County have a heightened awareness of water scarcity issues. New Mexico has experienced cyclical drought over the last few centuries, and these conditions are only expected to worsen with the impacts of climate change (Brookshire et al. 2013). On average, the Albuquerque area receives less than 25.4 cm (10 in.) of precipitation per year (Albuquerque Bernalillo County Water Utility Authority 2016).

Relating water scarcity to climate change, the survey's next question asked respondents "Do you believe that the impact of climate change on the water cycle will make it more difficult for ABCWUA to meet our community's water needs in the next 10 to 40 years?" To compare results with those from a previous study done by the ABCWUA, the phrasing of this question was taken directly from ABCWUA's periodic customer opinion survey, which was last conducted in February 2016. The ABCWUA survey took this question from a 2013 national survey conducted by the Water Research Foundation (WRF) (Raucher 2014) to better understand how the opinions of ABCWUA customers compared with national opinions.

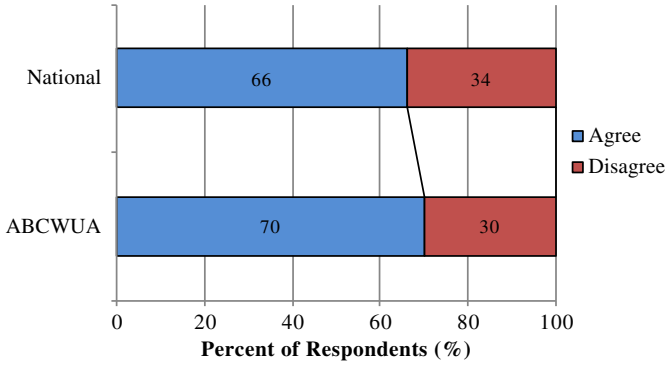

Fig. 1. Comparison between responses from a (Raucher 2014) national survey by the Water Research Foundation and ABCWUA (2016) survey to the question: "Do you believe that the impact of climate change on the water cycle will make it more difficult for [the local water utility] to meet our community's water needs in the next 10–40 years?".

Fig. 1 shows the comparison between the 2016 ABCWUA customer opinions and the 2013 national opinions on the impact of climate change on the water cycle. Fig. 1 shows that 70% of ABCWUA respondents agreed that climate change will have an impact on the water cycle and upcoming water needs, compared with 66% of the national respondents. Although the two surveys were conducted in different years, it is possible that ABCWUA customers have a greater awareness of water scarcity than the typical US resident due to living in a water-scarce desert environment with highly variable and limited precipitation.

Our survey yielded results similar to the ABCWUA's (2016) survey, with 71% of respondents answering "Yes," 14% answering "No," and 13% answering "I don't know." The ABCWUA and WRF surveys did not include an "I don't know" response option. The fact that 13% of the present survey respondents answered "I don't know" suggests that a significant proportion of the Albuquerque area population may be undecided or need more information to form an opinion on climate change.

Next, from a list of potential water sources, respondents were asked to select the source or sources from which the ABCWUA gets the water it serves to customers. The ABCWUA incorporates both groundwater and surface water into the potable water supply. Fig. 2 shows the breakdown of responses to this question.

About 48% of respondents chose the correct answer combination, "Groundwater and surface water," demonstrating that nearly half of respondents knew that Albuquerque's water is drawn from multiple sources. However, about 21% of respondents selected only "Groundwater," and an additional 16% did not know from where their water was sourced. These respondents' ignorance may be at least partly explained by the relatively recent addition of surface water to the water supply portfolio via the 2008 San Juan Chama Drinking Water Project, which involved diversion of Colorado River water to the Rio Grande (ABCWUA 2016). Perhaps some respondents were not aware of the San Juan Chama Drinking Water Project and/or its implications for their former groundwater-only water supply.

These results are not surprising because previous research has suggested that community members may not understand where their water comes from or have misconceptions about the sources and/or quality of their drinking water (Macpherson and Slovic 2011; Millan et al. 2015). For example, Gu et al. (2015) reported that only 20% of their study population in Tianjin, China, knew the actual source of their drinking water. Additionally, during the present study's focus groups, there were several participants who, when asked, "Where does your water come from?", replied, "The tap." This sort of response implies that knowledge about water sources and the urban water cycle in general may be limited for some members of the community.

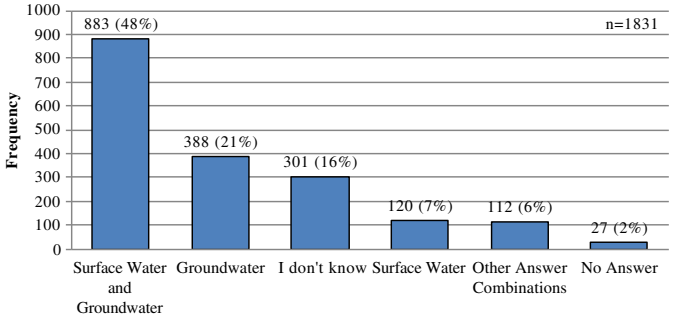

Fig. 2. Survey responses on the sources of Albuquerque's water supply.

Water Use at Home

The survey included a series of questions about water usage at home and respondents' perceived level of safety of bottled water relative to their tap water. These questions were based in part on a study by Millan et al. (2015). Regarding the type of water most often consumed at home, the survey data showed that 28% of respondents consumed city tap water as-is, 43% consumed city tap water that is filtered at home, and 18% consumed bottled water. Millan et al. (2015)'s findings about southern California voters showed a higher percentage of bottled water drinkers (31%), a lower percentage of respondents using city tap water as-is (21%), and a similar percentage of those who most often drink city water filtered at home (45%). The breakdown of responses from ABCWUA customers is shown in Fig. 3.

Next, perceptions of the safety of bottled water were examined. The survey found that 48% of respondents did not believe that bottled water was safer than Albuquerque tap water, whereas 29% believed that bottled water was safer. A cross examination of the responses to these last two survey questions suggests that a majority of bottled water drinkers might have misperceptions about the safety of bottled water: 77% of bottled water drinkers believed bottled water to be safer than Albuquerque tap water, whereas only 31% of filtered city tap water drinkers and 16% of city tap water drinkers believed bottled water to be safer.

The last question in this section of the survey asked about conservation measures at home, and respondents were able to select multiple response options. Several of the response options were adapted from Miller and Buys (2008), and others were added and refined during the focus groups conducted in preparation for this survey. As shown in Fig. 4, 78% of respondents practiced simple conservation measures such as turning off the tap while brushing teeth, 62% used water-saving fixtures like low-flow faucets and toilets, 59% have xeriscaped their land or yard, and 57% use water-efficient appliances like dishwashers and washing machines. Rainwater harvesting and not watering their land were much less common among respondents.

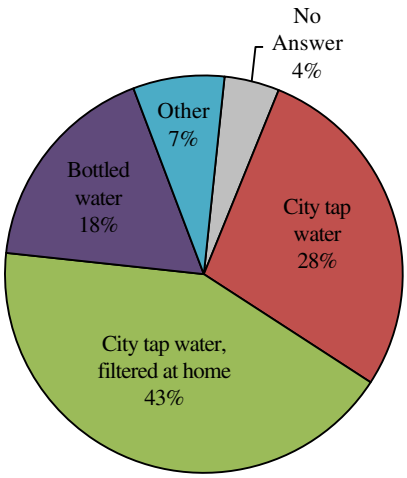

Fig. 3. Percent breakdown of water sources most often consumed at home by survey respondents, $n = 1{,}831$.

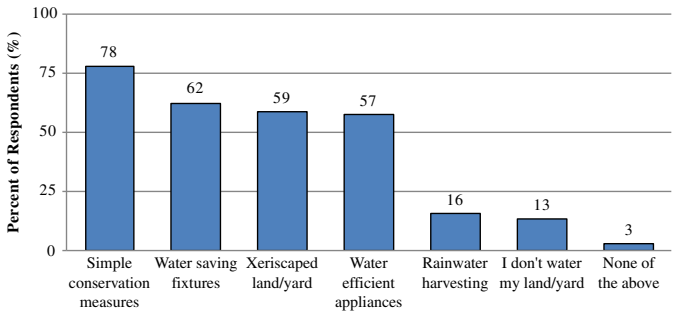

Fig. 4. Conservation measures at home by percentage of respondents.

Furthermore, the results showed that 64% of respondents practiced three or more water conservation measures at home, suggesting that the respondents were generally water-aware and working to conserve the resource. Similar to the present results, the survey by Miller and Buys (2008) conducted in Australia found that simple conservation measures (like turning off the tap when brushing teeth) were most popular. They also found a nearly identical percentage for the use of water-saving fixtures compared with the present survey's results. However, the two sets of results are difficult to compare because Miller and Buys (2008) sought to compare conservation behaviors between men and women, not to determine the general conservation behaviors of water users, and they collected responses on a 3-point scale.

As a transition into questions about acceptance of potable reuse, respondents were asked if they were "aware of the concept of purifying wastewater and reusing it for drinking water" because previous research suggests that prior knowledge or experience with water reuse influences acceptance (Dolnicar et al. 2011; Macpherson and Snyder 2013). Response options for this question were "Yes" or "No," and 68.5% of respondents indicated that they were aware of potable reuse. In Millan et al.'s (2015) study, 73% of respondents were either "Very" or "Somewhat" familiar with the concept of recycled water," whereas 27% were either "Not too familiar" or "Not at all familiar." Millan et al.'s (2015) respondents had previous experience with potable reuse projects, such as the unsuccessful push by San Diego, California, for IPR in the 1990s, along with extensive media coverage of the debates over water reuse, and the media has been shown to create knowledge and influence social norms related to potable reuse (Ching 2013). In contrast, there has been minimal public dialogue or media coverage related to potable reuse in Albuquerque.

Acceptance of Potable Reuse and Reasons for Support or Concern

The survey asked respondents about the two potable water reuse scenarios, DPR and IPR. Previously, IPR has been shown to receive more public support than DPR because the included environmental buffer is thought to provide a natural purifying step and serves to distance the water from its history as wastewater (Hartley 2006; Millan et al. 2015; Nellor and Millan 2010; Tchobanoglous et al. 2011).

Respondents were asked to rate their willingness on a five-point scale to accept DPR and IPR, as adapted from surveys by Macpherson and Snyder (2013) and Millan et al. (2015). Fig. 5 shows the breakdown of respondents' willingness to drink water in a hypothetical community that implements each type of potable reuse. The "Generally OK" category captured the most respondents for both DPR and IPR, with 34% and 37% of respondents, respectively. For both types of reuse the "Neutral" category captured about 21% of respondents. In line with the results of previous studies, DPR appears to be the less favorable option among this survey's respondents. However, different from previous studies, fewer of the present respondents indicated that they would refuse to drink the reuse water (DPR or IPR). For example, before

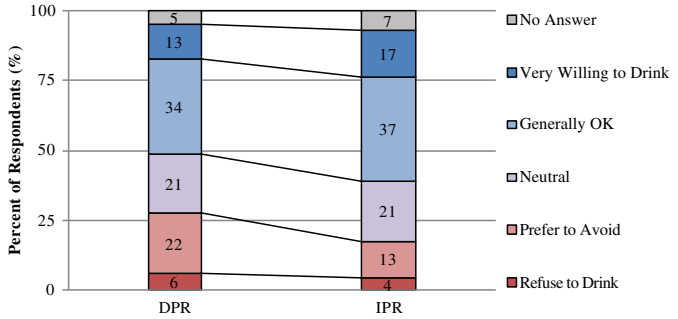

Fig. 5. Breakdown of acceptance by type of reuse, DPR and IPR.

exposure to tested messages, 40% and 14% of California voters surveyed by Millan et al. (2015) found use of "recycled water" for drinking to be "Completely unacceptable" or "Somewhat unacceptable," respectively.

The questions on willingness to drink the two different types of reuse water were followed by questions pertaining to possible reasons for support or concern for each type of reuse. The questions about support or concern allowed for multiple response options to be selected, and several of the response options were adapted from Millan et al. (2015) and refined during the focus groups with ABCWUA customers. A study by Macpherson and Snyder (2013) identified similar reasons for support or concern for recycled water. Fig. 6 shows respondents' reasons for support of DPR and IPR, ranked by the frequency of each answer.

For DPR, the data showed that 57% of respondents indicated support due to water shortage, drought, or limited supply, 45% were supportive because it reduces waste and uses resources efficiently, and 42% indicated support because it has been safely implemented in other cities. Similar to these results, Millan et al. (2015) also found that water shortage, drought, and limited supply were the main reasons respondents stated for supporting both IPR and DPR (36% and 44%, respectively). Among the present survey respondents, trust in the purification technologies was one of the least supported reasons for acceptance, with only 34% of respondents selecting this answer choice. The "Other" answer choice provided an opportunity to write in a response; however, the write-in responses are not included within the scope of this paper.

Results for IPR were very similar to those obtained for DPR. The IPR question included one additional answer option for support: the purified water passes through the environment before being treated and used again. This answer ranked relatively low compared with other reasons for support, with 33% of respondents selecting it. The authors expected this percentage to be higher because previous studies have suggested that the environmental buffer is the primary reason for higher public support of IPR versus DPR. Furthermore, in the previous survey question, only 4% and 6% of respondents said that they would "refuse to drink" IPR and DPR water, respectively; however, for this question, the percentage of respondents selecting "Not applicable—I would NOT be willing to drink the water" fell somewhere between the proportions of "prefer to avoid" and "refuse to drink" responses from the previous question. Clearly, there were some respondents who had not completely made up their minds or may have needed more information.

Next, the survey asked respondents about reasons they might be concerned with the two reuse scenarios. The response options were adapted from Millan et al. (2015) and refined based on recommendations from Macpherson and Slovic (2011) and the focus groups. Fig. 7 shows the results regarding concerns about DPR and IPR. Again, respondents were allowed to select multiple answer choices.

For IPR, the largest percentage of respondents, 38%, had no concerns about the reuse scenario, although 36% had concerns about safety and health. However, the main concern for DPR (41%) was that the water may not be safe. In contrast, Millan et al. (2015) found that the main reason for opposition to DPR was a lack of trust in the "filtering process/system," with 40% of respondents choosing this option. Only 17% reported a similar concern for DPR in the present survey. For DPR and IPR, similar proportions of respondents indicated that they do not trust the government or water utility, at 23% and 22%, respectively. This is in contrast to the Millan et al. (2015) results, in which only 1% of respondents had concerns stemming from a lack of trust. As compared with IPR, respondents to the present survey were slightly more concerned that the DPR water would have a bad smell or taste, and they were slightly less trusting of the purification technologies for DPR, even though the survey indicated that the technologies for IPR and DPR would be identical.

Trust in Institutions

Finally, the survey asked respondents about their level of trust in various entities to provide accurate information on water reuse and related safety issues. Following previous research that has linked a lack of acceptance of water infrastructure projects to distrust in various entities (Hurlimann and Dolnicar 2010; Ishii et al. 2015; Nellor and Millan 2010; Ormerod and Scott 2012), respondents were given a list of entities and asked to rate their level of trust

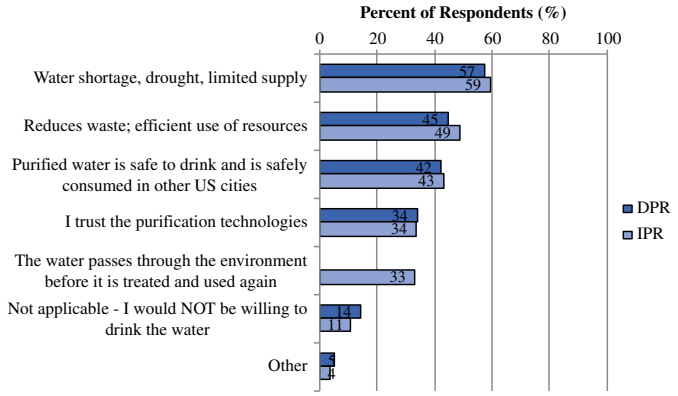

Fig. 6. Reasons for potable reuse support ranked by most frequent reasons for support.

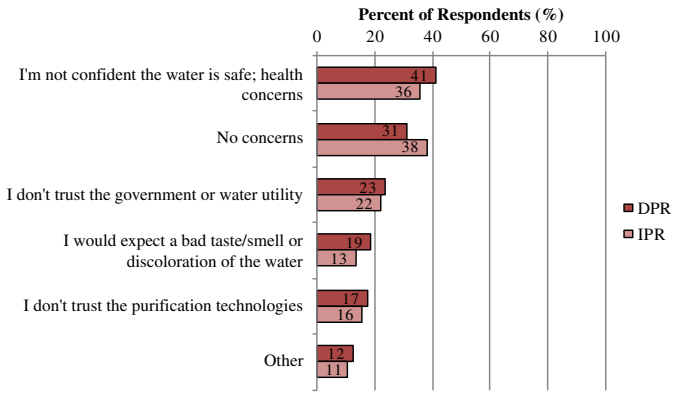

Fig. 7. Reasons for concern about potable reuse ranked by most frequent concerns for DPR.

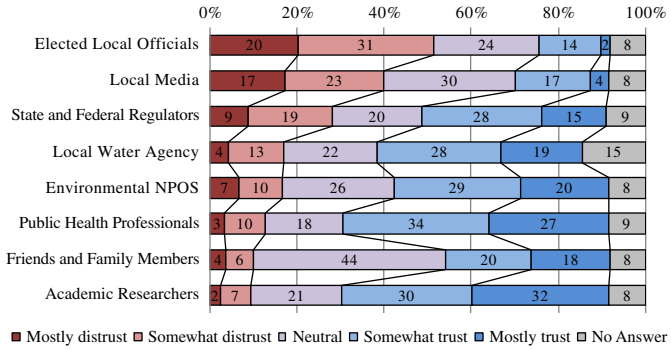

Fig. 8. Level of trust in various institutions to provide accurate information on water reuse, ranked by sum of the "mostly distrust" and "somewhat distrust" categories.

in each using the following scale: "Mostly distrust," "Somewhat distrust," "Neutral," "Somewhat trust," or "Mostly trust." Fig. 8 shows the results of this survey question, ranked by the sum of the "Mostly distrust" and "Somewhat distrust" categories.

These findings were similar to those of other researchers (Ishii et al. 2015; Millan et al. 2015; Nellor and Millan 2010; Ormerod and Scott 2012), except that the present survey respondents had less trust in the local water agency [e.g., results from Ormerod and Scott (2012) and Millan et al. (2015) ranged from 55%–59% trust in the agency]. Results also showed that 51% of respondents "mostly" or "somewhat" distrusted elected local officials, 40% of respondents distrusted the local media, and 28% distrusted state and federal regulators, such as the New Mexico Environment Department or the USEPA.

Among the most trusted entities were academic researchers and public health professionals, with just over 60% of respondents selecting either the "Mostly trust" or "Somewhat trust" categories. Due to the fact that academic researchers conducted this survey, the possibility for response bias on this question should be considered in assessing the result. The local water agency, ABCWUA, and environmental nonprofit organizations (NPOs) are moderately trusted, with 47% and 49%, respectively, falling into these categories. This information could be useful to ABCWUA in selecting the most appropriate sources and/or messengers to provide the public with information about potential future potable reuse projects.

Study Limitations and Assumptions

The authors acknowledge several limitations associated with their sampling methods. The population from which the sample was taken was ABCWUA residential account holders, who likely were mostly homeowners. Aside from addresses and other geographic information, the customer accounts log did not provide additional data. Without demographic data for all ABCWUA account holders, the authors were not able to check if the sample or survey data were representative of the population of interest or oversample specific populations that may have been less likely to respond to the survey (e.g., lower education levels). This lack of data on the population also resulted in an inability to calculate nonresponse error. Without a way to measure nonresponse error, the authors relied on the generally accepted proxy that as response rate increases, the nonresponse error naturally decreases (Dillman et al. 2014). The steps recommended by Dillman et al. (2014) were taken to maximize the response rate, including multiple contact attempts, allowing for responses via more than one survey mode (i.e., mail and online), offering an advance cash incentive of $2, and providing a stamped return envelope to facilitate the return process. The survey's response rate of 46% was on average between 15 and 20 percentage points higher than rates historically obtained for UNM surveys on the same population, and it is significantly higher than the rates reported in the literature for similar studies, suggesting that these efforts to maximize response rate were effective.

To understand the distribution of survey responses in the ABCWUA service area, the response rate was calculated for each Census tract surveyed, and the rates were plotted on a map of Bernalillo County, as shown in Fig. S2. The purpose of this exercise was to ensure that most responses did not come from a small number of Census tracts within the ABCWUA service area. Fig. S2 demonstrates that all but one Census tract was represented.

Because it is possible that most of the ABCWUA account holders are homeowners, renters who have utilities included as part of their rent paid to a landlord might not have been included in the study. Unfortunately, the survey did not include a question asking if the respondent was a homeowner or a renter at the address to which the survey was sent, and this information would have been useful. Those who rent are generally younger and possibly of lower economic status, so residents in these groups may be underrepresented by the survey sample; 76% of respondents were 45 years or older.

Another possible limitation, particularly in Albuquerque, which has a relatively high Spanish-speaking population [24.5% according to 2013–2017 American Community Survey (ACS) estimates, (US Census Bureau 2017a)], was that no aspect of the survey was conducted in Spanish due to timeline and budget constraints. Thus, the Spanish/Hispanic/Latino respondents likely were either bilingual or English-speaking only, suggesting that the survey might not have representation from Spanish/Hispanic/Latino ABCWUA account holders who speak only Spanish. In allocating resources for the various aspects of survey research, future research should weigh the potential benefits of a larger sample size against the gains possibly achieved by a more inclusive design, i.e., one that includes the option to take the survey in Spanish and/or other languages.

Table S2 aims to better display how this survey's respondents compared with residents over the age of 18 in Bernalillo County, New Mexico. Table S2 provides key demographic data from survey respondents for comparison with data from both Bernalillo County residents over the age of 18 and Bernalillo County householders over the age of 18, which were obtained from the 2013–2017 ACS 5-year estimates (US Census Bureau 2017b, c, d, e). Table S2 also provides the difference in proportions between the present survey and the ACS estimates for three demographic factors.

Although this comparison is imperfect, it suggests that current survey respondents are more similar to Bernalillo County householders than Bernalillo County residents in general, and that the results underrepresent younger residents, those of Spanish/Hispanic/Latino ethnicity, and those with lower levels of education when compared with Bernalillo County residents as a whole. This underrepresentation is recognized as a source of potential response bias of the conducted survey, and future research could take steps to mitigate these biases by oversampling from certain populations or offering the survey in other languages. Although this study's sampling approach had shortcomings, previous survey research at UNM with the same population of interest found this approach, as detailed by Thacher et al. (2011), to provide the most representative sample.

Conclusions and Future Research

Public attitudes toward water reuse in an arid inland context have not been adequately explored in the literature to date. In the first

large-scale survey in an arid inland community known to the authors, attitudinal data on water scarcity, climate change, water habits at home, trust in institutions, and acceptance of potable reuse were collected. Although it is recognized that the comparisons made to other studies are limited and differences between the present study and others may not necessarily be attributed to differences in context, the authors found that the survey population was very aware of water scarcity and seemed to be more accepting of potable water reuse than other populations that have been studied. Also, the studied population was less aware of planned potable reuse prior to the survey as compared with awareness in US coastal and Australian populations, where the topic has been debated and discussed in public. For a utility or community that is interested in the possibility of potable reuse, less prior knowledge may provide the opportunity to carefully craft informed and intentional education and outreach programs prior to potential dissemination of misinformation. To ensure as broad a reach as possible, education and outreach efforts should begin early and continue throughout the course of project conception and implementation.

Further, this survey was useful in identifying water-related misconceptions that can be targeted for correction through public education and outreach. For example, approximately half of survey respondents did not know exactly where their drinking water came from. Although this level of knowledge about drinking water sources was much higher than reported for other populations, it still suggests that a sizable portion of the population may have limited knowledge of local and regional water resources. Another misconception uncovered by the survey involved those who mainly drink bottled water and their perceptions about its safety relative to the city tap water.

It was also clear that although respondents were more convinced than most that climate change would affect future water supplies, there were still those who needed more information to make up their minds. Educating children and young adults about basic topics related to water resources, water scarcity, and the urban water cycle is essential to fostering continued interest in and knowledge of these topics. However, lack of knowledge on certain topics may not always be due to simple ignorance; myths or fears initiated and perpetuated by false or misleading information can be the source of misconceptions as well. It is also possible that misconceptions stem from a lack of trust in the entities providing information, a topic that should be explored in greater detail.

Our obtained survey data also indicated that potential negative health impacts of potable water reuse were a major concern. In addition to educational programming, opening a community dialogue about safety issues surrounding water treatment and potable water reuse may be an important step in helping the public understand its options for meeting potable water demands and making informed decisions about water resource management. This would also be an opportunity for the local water utility to build trust with its customers, especially in the case of the ABCWUA, which is less trusted than what has been reported for water utilities in other locations. In addition, the data collected regarding level of trust in various entities is useful in thinking about who would be the best messengers in communicating with the public about the safety of potable water reuse and related topics. Different from the results of other studies, this survey suggested that state and federal regulators are not always well-trusted by residents.

Conducting community surveys can be helpful in determining the types of information to include in educational programming and outreach efforts, and in identifying how different contexts can shape knowledge and perceptions. The methods and results of this survey may be useful to water utilities and other entities that are interested in conducting their own public surveys or creating public communication and educational programming related to reuse. As ABCWUA and other utilities in arid inland regions begin to include potable reuse in their long-term water planning, public education and outreach will be essential to the successful implementation of these projects.

Topics for future research include further investigation into the demographic associations with acceptance and other issues covered by this survey. For example, results showed that 41% of respondents had health concerns related to DPR, compared with about 36% for IPR. What demographic characteristics or other factors might explain this difference in concern? Such information could be used to target specific educational programming or outreach to certain groups (e.g., groups that may be receiving limited information on water scarcity and climate change) and to initiate targeted communication and dialogue with others (e.g., those who are more likely to be unwilling to accept potable reuse). Another topic for a future survey is the impact of costs on acceptance of different reuse scenarios. Future research could investigate a customer's willingness to pay for various reuse scenarios or determine the level of acceptance based on a standardized cost to the customer.

Data Availability Statement

The data set discussed in this paper has been published, along with instructions for interpretation and use, to aid in further research on water scarcity and climate change-related topics in arid inland areas (Distler and Scruggs 2020).

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Supplemental Data

Figs. S1 and S2, and Tables S1 and S2 are available online in the ASCE Library (www.ascelibrary.org).

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