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Reclaiming Suburbia: Differences in Local Identity and Public Perceptions of Potable Water Reuse

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Abstract: Urban water managers are increasingly interested in incorporating reclaimed water into drinking supplies, particularly in rapidly growing arid and semi-arid urban areas, such as the western United States. Northern Nevada is one location that is considering augmenting drinking water supplies with reclaimed water, a practice that is known as planned potable water reuse. Potable water reuse can expand water supply and reduce wastewater disposal. However, past studies have shown that the introduction of potable reclaimed water can be controversial and requires an understanding of public perceptions of the resource prior to implementation. This study explores the factors that influence whether or not respondents in northern Nevada express willingness to drink reclaimed water. We pay specific attention to the degree to which self-identification as an urban, suburban, or rural resident influences how people consider using treated wastewater for both potable and non-potable purposes. To address this, we conducted a survey to assess community perceptions of reclaimed water use and applications in northern Nevada in the spring of 2018. We find that years spent living in the home and a respondent being female are negative and significant predictors of being willing to drink reclaimed water, while having heard of reclaimed water before and self-identification as a suburban resident are positive and significant predictors. As the region becomes more developed, particularly in its growing suburbs, it is essential to understand the nature of the interests and concerns regarding water resources and the expanded use of reclaimed water.

Keywords: indirect potable reuse; public attitudes; water recycling; water reclamation; logit model

1. Introduction

Effective management of water and wastewater systems continues to be central to the protection of public health and the environment in the 21st century, however water supply, sanitation, and waste disposal pose vexing and geographically unique management challenges. In developing countries, the limited capacity of cities to adequately treat and dispose of wastewater causes substantial pollution and contributes to poor health outcomes. In middle and higher income countries, water reuse and recycling projects have long been used to respond to the pressures of growing water demands in the face of shrinking water supply [1]. As the global trend toward urbanization continues, numerous cities have harnessed technologies to assist with wastewater management and resource recovery in ways that facilitate water reuse and expand water supplies. Since wastewater is the only water source that grows in tandem to population, water planners view recycled water, also known as reclaimed water, as a reliable and independent urban water supply. Water reuse proponents suggest that water reuse represents a viable long-term solution to meet the future water needs of society, especially in arid regions facing water scarcity and variability in water supply. For example, the World Health Organization (2017) recently stated that, given continued population growth, urbanization, and the

impacts of climate change, "potable reuse represents a realistic and practical source of drinking-water in many circumstances" [2] (p. 1). The most notable examples of successful development of potable water reuse internationally include Windhoek, Namibia, Singapore, Orange County, California, USA, Perth, Australia, and Malahleni, South Africa [2,3]. When contextualizing the need for water reuse, scholars note the "emergence of a global water crisis", [4] (p. 83), which necessitates a more sustainable approach that includes nontraditional water supplies, like reclaimed water [5,6].

Facing current and future supply challenges, water managers in water-strapped communities are increasingly willing to consider "new paradigms for water supply and management" [7] (p.1) that provide opportunities to overcome fragmented approaches to water resources and provide for more holistic water management, which can maximize integrated collaboration, reduce inefficiencies, and mitigate water withdrawals [8,9]. As a result, water managers in cities with centralized sanitation systems increasingly view urban wastewater as a local resource that is capable of expanding local water supplies through greater water recycling [2,3]. The success of potable water reuse occurring in developed and middle-income countries indicates that it could be accepted more widely as a sustainable and potentially available 'new' water supply [1]. Nevertheless, human behavior, public attitudes, and opinions are critical to project success [8,10].

Reclaimed water can help cities to deal with water supply and disposal issues and is used in cities across the globe, including the United States (US), Middle East, Europe, Japan, Singapore, Australia, Israel, Latin America, and South Africa [3,11]. The use of reclaimed water for non-potable purposes (e.g., irrigation, industrial use) is relatively noncontroversial, however, more recently, potable water recycling projects are growing in number and size due to a combination of factors, including relative water scarcity, technological innovation, and greater institutional and public acceptance [3,11,12]. The most common form of potable water recycling is a practice known as "indirect potable reuse", which blends highly treated reclaimed water with conventional water supplies. Potable reuse projects, though, do require support from the general public in order to succeed [9,13,14].

With over a 50-year history in the United States of America (USA) and abroad, the concept of using reclaimed water to enhance drinking water supplies is nothing new. However, the rate of proposals for planned potable reuse is increasing and expected to grow by 61% by 2025 [3] (p. 1–6). Potable water reuse projects are typically classified to include either direct or indirect potable reuse [9]. Direct potable reuse schemes, which reuse highly treated wastewater from pipe-to-pipe without an intervening environmental barrier, are less common but growing in importance [3]. Indirect potable reuse (IPR) projects blend highly treated wastewater with conventional drinking water supplies, such as from groundwater or a reservoir, before delivering it through the municipal supply system to customers' taps. Although uncommon, such projects have been considered or are already in place in a number of high-growth urban areas, including Singapore, Australia, Namibia, and the US [3,9]. Indeed, IPR schemes currently serve millions of urban water users. Nevertheless, several proposed projects have failed as a result of resistance from a skeptical public [14–16].

Although wastewater can be treated to water quality levels that exceed drinking water standards, survey research has demonstrated high levels of public opposition to drinking reclaimed water when compared to non-potable urban, industrial, or commercial uses (applications such as landscape irrigation or process water) [3,14,17,18]. The most consistent factor known to influence public acceptance of reclaimed water, for potable and non-potable purposes, is the level of personal contact—referred to as the ladder of acceptance. Survey research suggests most people accept reclaimed water in cases where there is less personal contact, such as use in irrigation or toilet flushing, however, as potential uses move closer to personal contact, the level of support declines [14]. The "acceptance problem" has been one of the defining characteristics of the social scientific literature on public perceptions to potable water reuse [9,11]. Media and scholars most often attribute the lack of public acceptance to psychological factors, including repugnance, aversion, affect, and emotion [9,11,14,16,19,20].

The lack of public acceptance can pose a serious constraint on potable water reuse planning. As a result, water managers consider public perception of water recycling an important area of social scientific research [9,14,16]. The relationship between public acceptance and socio-demographic variables (e.g., age, gender, education, income, religion, race/ethnicity, political affiliation) has been studied extensively. However, comprehensive reviews of these studies reveal mixed results on the importance or significance of these relationships [14,16]. Scholars have observed differences in public attitudes between nations [18,21–24] and cities [25,26]. These findings signal that there is spatial variation in responses across geography, but there have been few attempts to analyze this variation within a particular city or region. Garcia-Cuerva [27] noted a statistically significant difference in reclaimed water support between Americans who identified their residence as metropolitan or rural, with a higher percentage of "reclaimed water supporters" in the metro category. Hurlimann [26] compared the differences in perception of reclaimed water between two commercial building users in Australia and did not find a significant difference in happiness to use non-potable reclaimed water between those in the urban and rural buildings. While this study did explore differences between respondents' perceptions of reclaimed water use in urban and rural areas, it only sampled survey respondents in two buildings, with one in each environment. No attempt yet has been made to comprehensively understand these distinctions between a wider sample of urban, suburban, and rural respondents throughout a community, which is a priority research area for urban water governance. This study seeks to address this gap.

Given that water related risks emerge from a complex interaction between humans, environment, and technology, additional social factors have also been known to significantly impact public responses to reclaimed water. Potentially significant social factors include perceptions of fairness, trust in water institutions, cost concerns, and prior knowledge of (or experience with) reclaimed water [9,10,14,16]. Previous knowledge of reclaimed water use is uneven and it varies from one community to another. The reported percentage of respondents with prior knowledge of water reuse ranges from 28% in a study in India [21] to 90% of respondents in Beijing, China [18]. In the western USA, a study in Oregon found that 75% of survey respondents expressed a familiarity with the term "recycled water" [28]. Not surprisingly, perceptions of public safety and health risks have also been found to be paramount to public acceptance of potable and non-potable reuse [11,16]. Best practices for proponents of potable water reuse strongly suggest early public engagement, outreach, and sustained involvement to encourage public endorsement [3].

The primary debate in the literature is the degree to which the lack of public acceptance of recycled water is psychological disgust or social and cultural context [10]. Psychological disgust is typically explained as an emotional response prompted by the deeply ingrained "yuck factor" [9,20,29]. Social and cultural objections include influential factors, such as prior experience, perceptions of fairness, trust in water authorities, or the longstanding public health practice of separating sewage from drinking water [4,10,30]. Following in line with social and cultural approaches to understanding public perceptions, this study explores if the way people think about their residential identity—as urban, suburban, or rural—has any relationship with how they think about the appropriateness of reusing treated wastewater for potable and non-potable purposes.

In this study, we consider the case of treated wastewater for potable and non-potable uses in the Reno–Sparks metropolitan area in northwestern Nevada. It is home to roughly 15.4% of the state's current population [31], and has experienced rapid growth in recent years. Like many cities in the western USA, the region faces regional water supply and disposal challenges that could be mitigated by greater use of reclaimed water. It is unknown, though, to what extent residents in northern Nevada are aware of, or have heard of, reclaimed water use, which studies have found to be a significant predictor of public acceptance of reclaimed water's integration into regional water supplies [14]. Reclaimed water use in Reno-Sparks is currently limited to non-potable purposes, however regional partners are exploring the feasibility of indirect potable reuse (IPR) to serve areas in and around the metropolitan

area of the Reno-Sparks [32]. The public's perceptions and willingness to consider a greater integration of reclaimed water in its water supply in the Reno-Sparks region is currently unknown.

This study seeks to identify factors that influence public responses to reclaimed water use [16] in the Reno-Sparks metropolitan area, and adds to the understanding of public response to potable water reuse by exploring the politics of place in relation to potable water reuse, "understood in terms of proximity, identity, and local differentiation and resulting spatial identities and horizontal relations"(p. 28) [11]. As water planners increasingly shift towards incorporating nontraditional sources in their supplies, such as reclaimed water, we help to inform the debate about public perceptions of risk while providing baseline information about social-spatial preferences and community attitudes about water reuse in a region where little research has been done on the perceptions of risk or attitudes toward reclaimed water.

In this study, we ask the following research question: how does the public of greater Reno-Sparks currently consider and perceive reclaimed water use? Specifically, what factors influence higher or lower levels of public willingness to consider the inclusion of reclaimed water as a means to enhance drinking water supplies? Finally, to what extent does residential location within the region influence this consideration? In doing, we answer Beveridge and colleagues' call to explore the "under-researched" spatial and political dimensions of water reuse [11] (p. 22). In what follows, we explore whether how people classify their residential identity—as urban, suburban, or rural—corresponds to how they think about the appropriateness of reusing treated wastewater for potable and non-potable purposes. The public attitudes toward potable water reuse assessed in this study incorporate respondents' perceptions of alternative water resources and community type. Our findings suggest that social-spatial understanding regarding residential location is central to public opinions about potable reuse. This study provides an alternative explanation for understanding the diversity of relationships that shape public responses to the prospect of potable water reuse as an option to increase water supplies.

2. Potential for IPR in Reno-Sparks, Nevada, USA

Local agencies and water providers are interested in exploring ways to reduce the cost of water in order to maintain low water rates for users. In several areas of northern Nevada, water is increasingly expensive due to the need to import water supplies from other basins or to acquire additional water rights to provide sufficient water supply to residents [32]. As the northern Nevada urban population grows, local agencies view potable reuse as a means to simultaneously augment water supplies while minimizing wastewater disposal. Potable reuse in the Reno-Sparks region was facilitated by the recent adoption of regulations allowing for IPR in Nevada [33].

The Consensus Forecast for 2018–2038 estimates the population of Washoe County, the county that contains Reno and Sparks, to grow from a population of 450,747 to 548,187 by 2036 [34]. Regional partners are investigating the feasibility of IPR in the region as part of the Nevada Water Innovation Institute, a coalition which includes individuals from Washoe County, City of Reno, City of Sparks, Western Regional Water Commission, University of Nevada, Reno, Truckee Meadows Water Authority, and Nevada Department of Transportation Stormwater Division [35]. The partnership aims to explore the technical feasibility of IPR in Reno-Sparks. Recent triple-bottom-line analysis of IPR in the region suggests that the proposed project could "nearly double local water resources availability" [32] (p. 759).

3. Materials and Methods

In order to assess the nature of the relationship between residential location and public perceptions of reclaimed water use and considerations, a survey instrument was developed and disseminated to a representative sample of northern Nevada residents in the spring of 2018. Such survey instruments are common ways to measure public opinions of reclaimed water use [18,24,25,36–40], though none has explicitly measured how opinions and perceptions vary across urban, suburban, and rural respondents within a specific geographic region. Additionally, this survey was the first to be distributed to residents

of northern Nevada that gathered empirical data about public perceptions of reclaimed water use. As such, it was also developed to provide a baseline understanding of public responses to water resource management in the region, which may affect the current and future utilization of reclaimed water resources.

The survey was distributed to residents who lived within the Truckee Meadows Service Area (TMSA) boundary (Figure 1). The TMSA is "the area within which municipal services and infrastructure (including potable water supply, reclaimed water supply, sanitary sewer, flood management, transportation [streets, transit, pedestrian, bicycle], public safety, parks, and schools) will be provided" [41] (p. 3). The "Truckee Meadows" refers to the areas of Reno and Sparks that are immediately adjacent to the Truckee River, whose water originates as snowfall on the Sierra Nevada mountain range in the neighboring state of California. The TMSA service area boundary extends beyond the Truckee River watershed to include the surrounding communities.

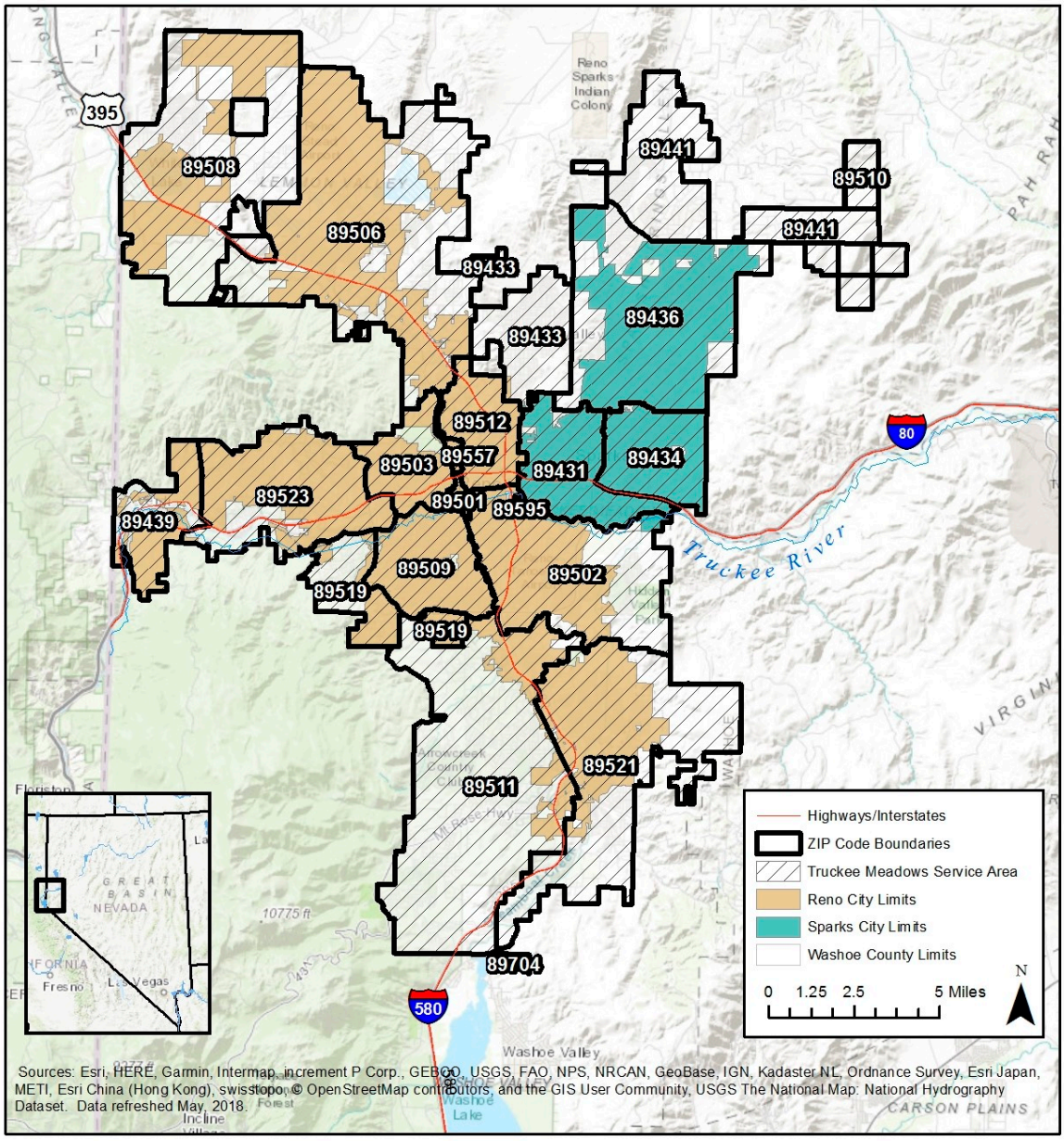

Figure 1. Truckee Meadows Service Area boundary and ZIP code boundaries: Reno-Sparks, area.

The survey instrument was a self-administered questionnaire, mailed to 4000 members of the public who lived within the TMSA boundary. We chose to distribute surveys using a systematic random sample of addresses that were within ZIP codes inside the TMSA boundary area. This technique allowed for us to gather a representative sample of residents within the TMSA boundary. The invitation and questionnaire was a printed document on University of Nevada, Reno (UNR) letterhead in English. Respondents recorded their answers and mailed it back to the study team using a prepaid envelope. The questionnaires were mailed in April 2018 and responses were collected through July 2018. The Internal Review Board (IRB) at UNR approved the survey instrument and recruitment procedures in advance of data collection and analysis. The two-page questionnaire collected information about (1) how water was distributed to and from the respondent's home location; (2) respondent perceptions of local water conditions (water quality, taste, affordability, reliability, and concerns about long-term supply); (3) whether or not the respondent had heard of reclaimed water before; (4) willingness to consider reclaimed water for a variety of potable and non-potable uses; (5) stated willingness to drink reclaimed water; and, (6) self-reported residential location type. Survey respondents provided these answers through multiple choice questions or Likert scale responses. Survey research has been the predominant mode of gathering public opinions about reclaimed water [17]. Likert scale questions are common within this research to judge scale of support/opposition approval/disapproval of reclaimed water applications and related topics [39,42–45]. Each of these questions allowed respondents to either not enter an answer or provide an answer of "do not know" or "unsure". These questions prompted respondents to describe the characteristics or perceptions noted in past studies on reclaimed water use, such as willingness to consider reclaimed water use in applications that included laundry, cooking, cleaning, and watering lawns. The full survey instrument is available online (see supplementary materials).

Information about stated willingness to drink reclaimed water was collected by prompting respondents to consider the following question: "Would you be willing to drink reclaimed water if it matched or exceeded current tap water quality?", where respondents indicated "yes", "no", or "unsure". To provide clarity for this question, a description of reclaimed water was included, which stated:

> "Treated wastewater (sewage effluent) is normally discharged into rivers, but can be reclaimed for recycling. In fact, reclaimed water is also known as recycled water. 'Reclaimed water' is typically defined as the use of treated wastewater for a beneficial purpose. The type and level of wastewater treatment determines the water quality".

Potable reuse was also briefly described in the questionnaire for the benefit of respondents, as follows:

> "[r]eclaimed water can be used to supplement the drinking water supply. In most places, this means adding highly treated reclaimed water to the underground water table and later pumping the blended water to utilities for treatment and delivery".

In addition, we focused on the geographic location of a resident within the region. To collect these data, we prompted respondents to categorize their household location by asking, "What category best describes where you live?", where response options included "city/town", "suburb", and "countryside/rural". Using this approach, we allowed respondents to self-identify where they considered their home to be within the region. An area can be classified as suburban, urban, or rural using a variety of different definitions that may focus on physical, economic, and/or cultural characteristics, and these uncertainties warrant attention in relation to how we collected this information for the study.

The United States Census Bureau defines urban and rural using a population threshold. "Urbanized areas" are areas with 50,000 or more people and "urban clusters" are another classification, including areas with at least 2500 but not more than 50,000 people. "Rural" encompasses all areas

outside of these parameters [46]. "Suburban" is not an official classification within the Census Bureau but it is lumped within "urban" or "rural" categories. Despite this, recent survey research has demonstrated that 53% of respondents in the United States classify themselves as suburban [47]. Multiple disciplines have attempted to characterize and define "suburban" areas in order to better understand the occupants and develop a metric to compare research on topics like urbanization and the urban-rural boundary [48–51]. Despite these efforts, an unambiguous definition of suburban versus urban or rural is not universally used. Given these uncertainties, we ultimately opted to rely on self-reported categorization to determine residential location in this study for two reasons. The first is because ZIP code boundaries in Washoe County include a mixture of residential location types within each of these three residential location types of interest and therefore could not be used to infer or confirm residential location of the respondents (Figure 1). The second is that formal designations of land used by agencies within the TMSA are meant to control for density and development type, not reflect community identity. These formal classifications can also change over time, depending on the adoption of new master plan or zoning policies. Categorization using formal land designations would be a highly uncertain process for this study.

Prior to analyses the survey responses were recorded and checked for completeness. We considered survey responses to be suitable for analysis if greater than 50% of questions were completed. No surveys completed by a member of an IRB-identified vulnerable population were recorded and analyzed. All data were then entered into the database and prepared for analysis. First, we compiled descriptive statistics for all survey question responses. We examined the descriptive statistics by levels of stated willingness to drink reclaimed water to identify initial indications of relationships and variations across this key question of interest. Subsequently, we compared responses to Likert-scale questions about perceptions of local water conditions and levels of support for the use of reclaimed water in non-potable applications, both by stated willingness to drink reclaimed water and by residential location type. Finally, we specify two binary logistic regression models, where stated willingness to drink reclaimed water or not is entered as the dependent variable and it is the discrete choice of interest in this study. In this modeling framework, we enter respondent characteristics and survey responses as covariates to determine to what extent these influence whether a respondent is unambiguously willing to drink reclaimed water or not.

4. Results

We present the results in four sections. First, we report summary statistics of respondent characteristics and survey responses by stated willingness to drink reclaimed water. Next, we consider respondents': (1) perceptions of local water conditions and (2) support for a variety of applications for reclaimed water. We consider these in separate sections, and in each, we assess how responses vary both by stated willingness to drink reclaimed water and residential location within greater Reno-Sparks (i.e., urban, suburban, rural region of the Truckee Meadows Service Area). Afterwards, we specify two logit models that examine key differences between respondents that indicated that they accept using reclaimed water to supplement drinking water supplies (i.e., willing drinkers) and those that expressed at least some level of reservation about drinking tap water blended with reclaimed water (i.e., non-wiling drinkers). The first model includes respondent characteristics and survey question responses, while the second adds the effect of stated residential location on stated willingness to drink reclaimed water or not.

4.1. Descriptive Statistics

In total, we received 474 valid survey responses, for an overall response rate of 11.9%. Survey-based water reuse studies over the last 20 years are often published without mention of response rates [14] however the published reports range from 77% for in-person interviews in Kuwait [23], 50% for in-person interviews in Israel [36], 46% survey by mail of registered voters

in Oregon, USA [28], 22% for an online survey in Australia [6], to 10.5% for a similar postal survey in southern Arizona, USA [44], which is the most similar survey methodology to that of this study.

Of the 474 respondents, 165 (35%) indicated that they would be willing to drink reclaimed water if it matched or exceeded their current water quality (i.e., willing drinkers) by answering "yes" to the survey question, while 181 (38%) stated "no" (i.e., unwilling) and 125 (26%) responded that they were "unsure". The remaining three respondents did not provide an answer to this question. Thus, nearly one-third of survey respondents in greater Reno-Sparks stated that they are willing to consider drinking reclaimed water to augment their supply, while the remaining two-thirds expressed at least some degree of reservation about doing so. We contextualize the level of support for potable reuse relative to other studies in the discussion section below.

Overall, Table 1 shows the majority of respondents are served by public utilities/companies for both water supply (92%) and sewer disposal (82%). Only 7% of respondents get their water from a domestic well, while 16% dispose of household water in septic systems. The remaining respondents indicated that they were unsure about where they get their water or how wastewater is disposed. The majority of respondents (76%) drink tap water most often (35% tap and 41% filtered tap water), while 17% reported they mostly drink bottled water.

Table 1. Summary Statistics: Willingness to Drink Reclaimed Water.

Factor (% Occurrence)	Stated Willingness to Drink Reclaimed Water						Total (n = 471) [1]	
	Yes (n = 165)		No (n = 181)		Unsure (n = 125)			
Demographics	**Mean**	**SE**	**Mean**	**SE**	**Mean**	**SE**	**Mean**	**SE**
Female	35.2	3.7	46.4	3.7	50.4	4.5	43.5	2.3
Male	64.2	3.7	49.7	3.7	44.8	4.5	53.6	2.3
18 to 24	0.0	0.0	0.01	0.01	0.01	0.01	0.01	0.01
25 to 44	19.4	3.1	10.5	2.3	12.8	3.0	14.3	1.6
45 to 64	38.2	3.8	38.7	3.6	37.6	4.3	38.2	2.2
65 and over	41.8	3.9	49.7	3.7	48.0	4.5	46.2	2.3
Water Consumption and Distribution	**Mean**	**SE**	**Mean**	**SE**	**Mean**	**SE**	**Mean**	**SE**
Drinks Tap Water	39.4	3.8	28.7	3.4	39.2	4.4	35.2	2.2
Drinks Filtered Water	43.0	3.9	39.8	3.6	38.4	4.4	40.7	2.3
Drinks Bottled Water	14.0	2.7	20.8	3.1	16.8	3.4	17.2	1.7
Water Supply: Utility	92.7	2.0	89.0	2.3	96.0	1.8	92.2	1.2
Water Supply: Well	6.7	1.9	9.4	2.2	4.0	1.8	7.0	1.2
Water Disposal: Septic	16.4	2.9	15.2	2.7	16.0	3.3	15.7	1.7
Water Disposal: Utility	82.3	3.0	83.1	2.8	80.8	3.5	82.3	1.8
Heard of Reclaimed Water Before	95.8	1.6	84.0	2.7	77.6	3.7	86.4	1.6
Residential Characteristics	**Mean**	**SE**	**Mean**	**SE**	**Mean**	**SE**	**Mean**	**SE**
Urban	37.0	3.8	51.4	3.7	41.6	4.4	43.7	2.3
Suburban	54.0	3.9	32.6	3.5	52.0	4.5	45.2	2.3
Rural	8.5	2.2	14.4	2.6	6.4	2.2	10.2	1.4

[1] Three respondents out of the full sample of 474 did not answer the question.

The majority of the respondents (87%) indicated that they had heard of reclaimed water before receiving the study questionnaire, which was a higher level than anticipated. However, we find that 96% of willing drinkers indicated they had heard of reclaimed water before, which is higher than both unwilling (84%) and unsure drinkers (77%). This suggests that there may be a relationship between stated willingness to drink reclaimed water and a respondent's familiarity with using reclaimed water for beneficial purposes, even though overall familiarity in this region is quite high.

We observe several other important differences between willing, unwilling, and unsure drinkers, as indicated in Table 1. First, a greater percentage of male respondents were willing drinkers, while women indicated that they were unsure about drinking reclaimed water at higher rates than men. Willing drinkers tend to be younger relative to unsure and unwilling drinkers, though there are notably

few responses from those aged 18 to 24 overall. Unwilling drinkers expressed the highest reliance on bottled water, as their primary source of water and were the least likely to list tap water as their primary water source.

Across respondents, 206 (44%) identified their residential location as one in a city/town (classified as "urban"), 211 (45%) as a suburban location, 48 as (10%) countryside/rural (classified as "rural"), while nine did not answer the question (2%). There are some notable differences observed between those willing, unwilling, and unsure drinkers across self-described residential location type, indicating the presence of a relationship between the spatial location of residents within Reno-Sparks and a willingness to drink reclaimed water. Suburban respondents comprise nearly 55% of willing drinkers, while nearly 52% of unwilling drinkers indicated that they lived in urban areas. Rural respondents most commonly identify as unwilling drinkers, and only one-third of unwilling drinkers are suburban respondents.

We also observe that one-third (33%) of survey respondents indicated that they lived in their current homes for less than five years, which is unsurprising given Reno's recent growth. However, unwilling and unsure drinkers tend to have lived in their present home longer than willing drinkers (Figure 2). The highest observed value for years living in the present home is 42 for willing drinkers, while some unwilling and unsure drinkers have lived in their home over 50 years.

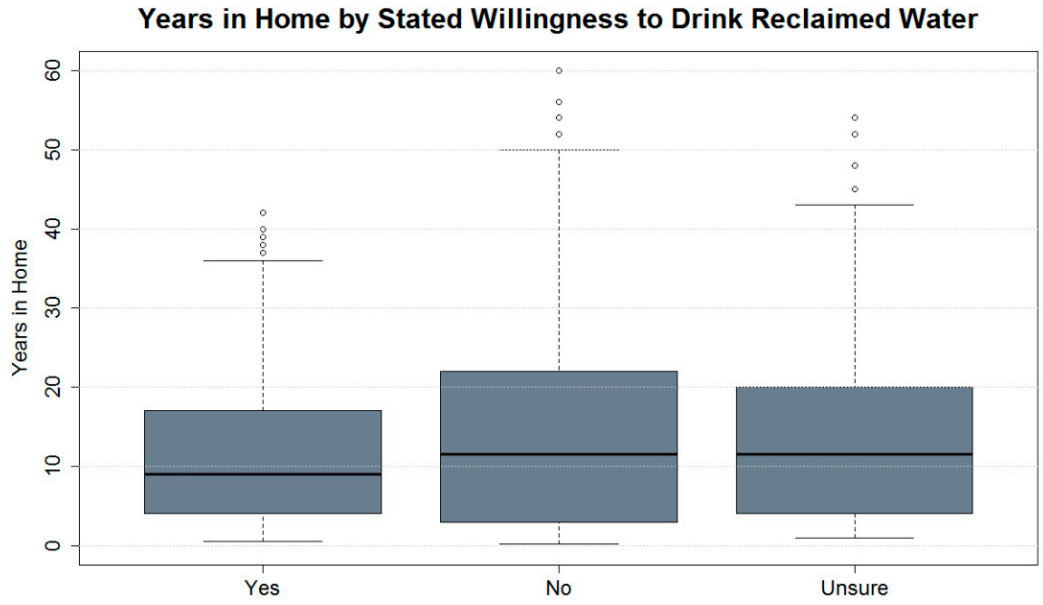

Figure 2. Distribution of total years that respondents have lived in their present home, by stated willingness to drink reclaimed water.

4.2. Perceptions and Concerns of Local Water Conditions

Willing drinkers expressed higher levels of agreement that they were satisfied with the taste, quality, and reliability of their current water supply. They also agreed at higher rates that their water bill was affordable when compared to unwilling or unsure drinkers. Figure 3 illustrates the relative average level of satisfaction with local water conditions between respondents based on their willingness to drink reclaimed water. Unwilling drinkers were generally less satisfied with water taste and quality of their supply than willing and unsure drinkers.

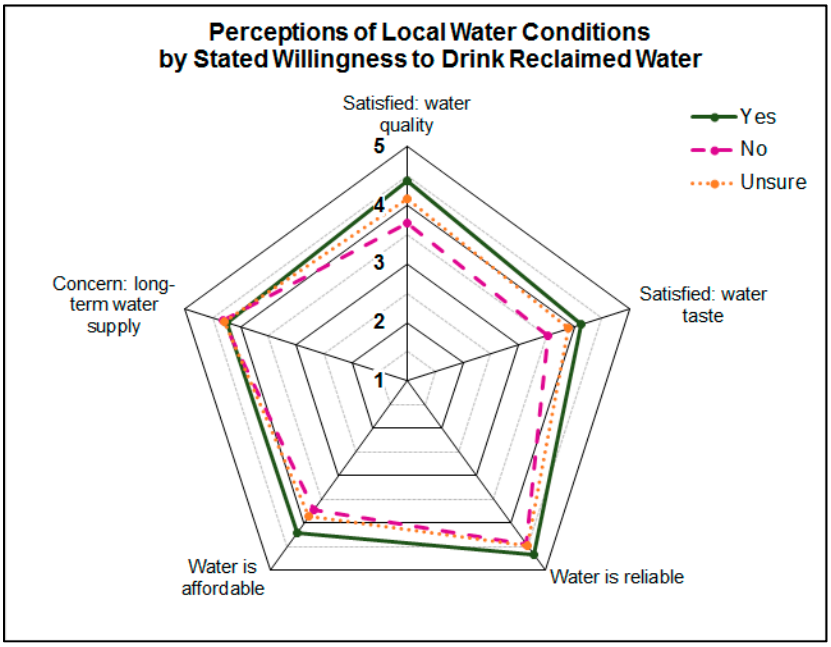

Figure 3. Average Likert scale responses to perceptions of local conditions, by stated willingness to drink reclaimed water. 1 = Strongly Disagree, 2 = Disagree, 3 = Neutral, 4 = Agree, 5 = Strongly Agree.

The relative average level of satisfaction with local water conditions between respondents based on their self-reported residential location is illustrated in Figure 4. Suburban respondents were the most satisfied with water taste and quality. While both suburban and rural respondents agreed at similar rates that their water bill was affordable, urban residents were less likely to consider their water bill to be affordable. Urbanites expressed slightly lower levels of satisfaction with water taste than other residents. Rural respondents were distinct in their lower level of agreement that they had a reliable water supply, indicating a geographic unevenness in the perceptions of water security.

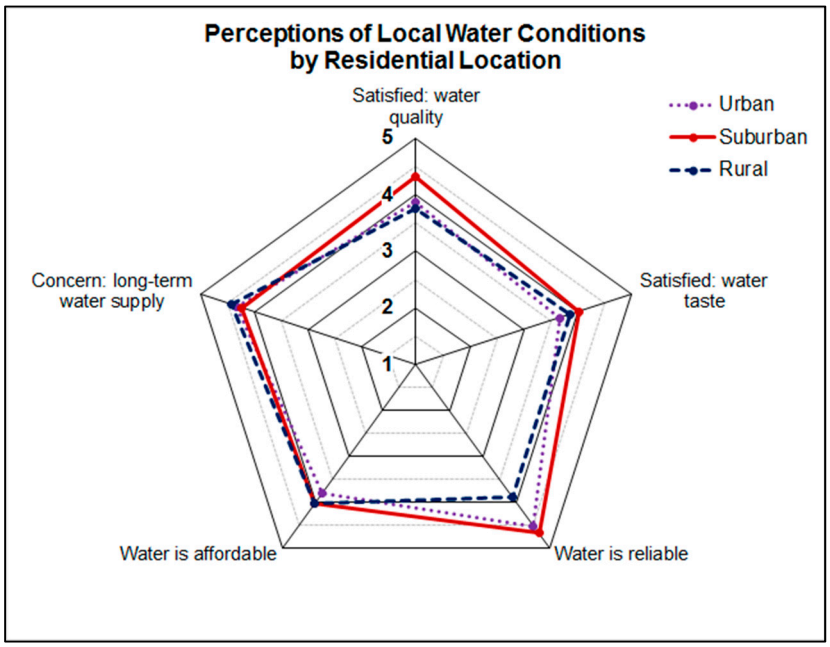

Figure 4. Average Likert scale responses to perceptions of local conditions, by residential location. 1 = Strongly Disagree, 2 = Disagree, 3 = Neutral, 4 = Agree, 5 = Strongly Agree.

As Figures 3 and 4 illustrate, concern about long-term water supply in northern Nevada elicited a consistent reaction from all survey respondents—regardless of the levels of stated willingness to drink reclaimed water and residential location type, respondents similarly agreed that this was a priority consideration. This result suggests widespread perceptions of uncertainty regarding future water security in the region.

4.3. Support for Other Applications of Reclaimed Water

Next, we consider the levels of support expressed for using reclaimed water in other applications besides personal willingness to drink tap water blended with reclaimed water. For these questions, respondents rated their support for reclaimed water uses more generally. Figure 5 demonstrates that willing drinkers consistently support the use of reclaimed water in other applications at higher rates than unwilling and unsure drinkers, and that the rank-order of support does not change across applications. Unsure and unwilling respondents also frequently have agreement levels that are more similar to each other than willing drinkers. This is not especially surprising, but it does indicate that support for drinking reclaimed water corresponds more generally to support for reclaimed water use in a variety of applications in this region. The applications with the most distinctly different responses are those involving close personal contact, including bathing, cooking, cleaning, and drinking. In these cases, willing drinkers generally support using reclaimed water for these purposes, while unsure and unwilling drinkers do not. Notably, there are four application areas where support for reclaimed water use is relatively high, even among unwilling and unsure drinkers: industrial purposes, watering both public parks and household lawns, and toilet flushing.

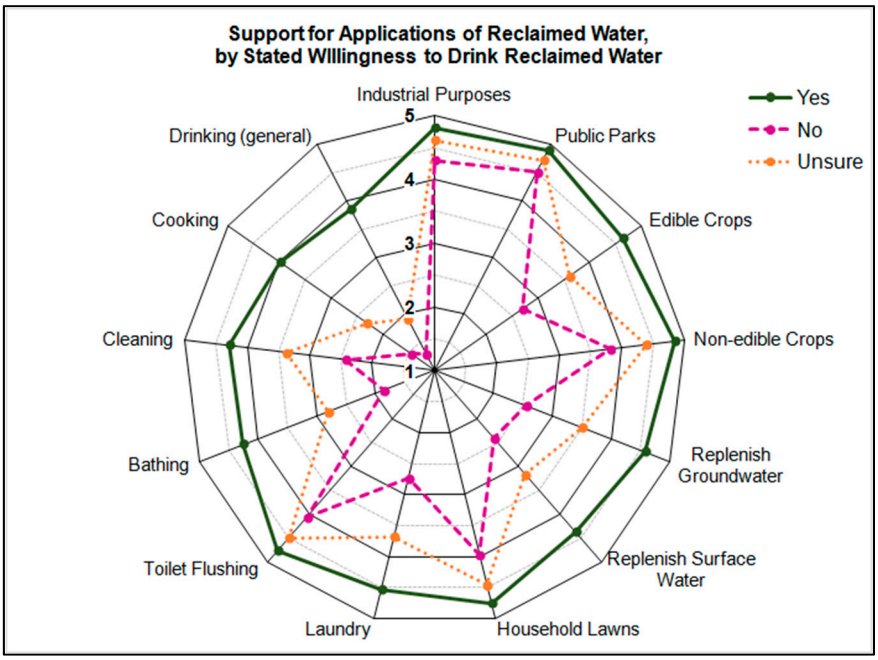

Figure 5. Average Likert scale responses for support for various reclaimed water applications, by stated willingness to drink reclaimed water. 1 = Strongly Oppose, 2 = Oppose, 3 = Neutral, 4 = Support, 5 = Strongly Support.

A key observation is that suburban respondents consistently support the use of reclaimed water in other applications at higher rates than urban or rural respondents, as illustrated in Figure 5. Furthermore, rural respondents consistently demonstrate lower rates of support for reclaimed water use across applications compared to suburban and urban respondents. As with stated willingness to drink responses (Figure 3), the rank-order position of support between suburban, urban, and rural respondents does not change across applications (Figure 6). This is a noteworthy finding, indicating

that suburban respondents appear to be more personally amenable to drinking reclaimed water than their rural and urban counterparts, and further, that they are more supportive of its use across all applications.

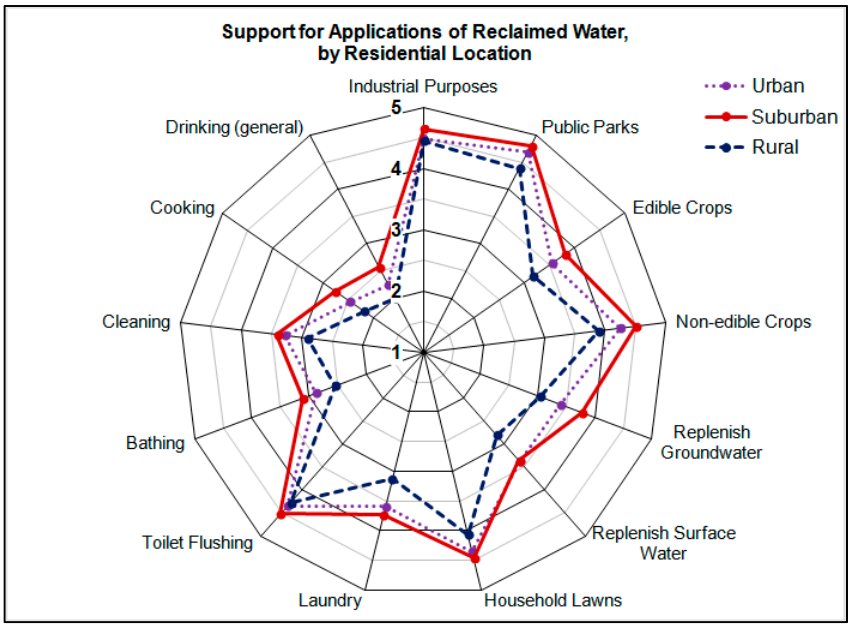

Figure 6. Average Likert scale responses for support for reclaimed water use applications, by residential location type. 1 = Strongly Oppose, 2 = Oppose, 3 = Neutral, 4 = Support, 5 = Strongly Support.

4.4. Willing Drinker Logit Model Specification

The previous two sections described the ways in which willing drinkers differ from both unwilling and unsure drinkers, who tend to have more similar responses to each other. Given our interest in understanding how willing drinkers vary from other respondents, and the descriptive statistics presented in the previous two sections, we next explore differences between those who clearly indicate they are willing drinkers and those who are not (unsure and unwilling drinkers). To do so, we specify two binary logit models that assess how respondent characteristics, stated perceptions, and residential location influence whether a respondent is a willing drinker or not, which is entered into each model as the dependent variable.

The first logit model includes non-spatial characteristics, while the second introduces a variable that specifies the residential location type within Reno-Sparks that was selected by respondents (i.e., city/town, suburb, countryside/rural). This allows for us to measure the extent to which residential location influences potable reuse acceptance (i.e., being a willing drinker or not), and it also allows us to determine to what degree the inclusion of this spatial variable improves model fitness. We enter a dummy variable that indicates whether or not the respondent is a suburban resident, given the findings in the previous sections that identify the distinct characteristics and perceptions of suburban respondents relative to those who self-identify as urban or rural. The results of the logit models are illustrated in Table 2.

The first logit model, which does not include spatial characteristics, illustrates that a respondent indicating that they had heard of reclaimed water before has a strong positive and significant influence on their willingness to drink reclaimed water (OR = 6.87). Similarly, support for using reclaimed water in a near-contact manner—cleaning purposes, in this case—is also a positive and significant variable (OR = 1.01). The results indicate that a respondent being female reduces the likelihood of being a willing drinker by 32%. Length of residence is also significant. Each additional year that a respondent has lived in their current home reduces the odds of being a willing drinker by 2%. The second model illustrates that a respondent living in a suburban area is a positive and significant predictor of being a

willing drinker (OR = 1.52) in the second model. The direction of the relationships of the other four covariates and their significance are maintained when adding the suburban resident dummy variable, and the model fitness improves.

Table 2. Willing drinker logistic regression model results.

Respondent Characteristics and Perceptions							
Coefficients	***Est.***	***OR***	***SE***	***Confidence Intervals***		***Z***	***p***
				2.5%	**97.5%**		
Heard of reclaimed water (%)	1.92	6.87	0.51	1.03	3.06	3.81	<0.01 **
Female (%)	−0.48	0.62	0.21	−9.02	−0.07	−2.28	0.02 **
Years in Home	−0.02	0.98	0.01	−0.04	−0.01	−2.74	<0.01 **
Support: cleaning (%)	0.01	1.01	0.01	−0.01	0.04	1.84	0.07 +
Constant	−1.91	0.15	0.52	−3.06	−0.98	−3.67	<0.01 **
Model Diagnostics							
Log Likelihood	−276.2						
LR Test (*p*)	<0.01						
AIC	562.4						
Respondent Characteristics, Perceptions, and Residential Location							
Coefficients	***Est.***	***OR***	***SE***	***Confidence Intervals***		***Z***	***p***
				2.5%	**97.5%**		
Heard of reclaimed water (%)	1.86	6.45	0.51	0.09	3.00	3.68	<0.01 **
Female (%)	−0.44	0.65	0.21	−0.09	−0.02	−2.04	0.04 **
Years in Home	−0.02	0.98	0.01	−0.04	−0.01	−2.51	0.01 **
Support: cleaning (%)	0.01	1.01	0.01	−0.01	0.04	1.91	0.06 +
Lives Suburban Location (%)	0.42	1.52	0.21	0.01	0.82	2.00	0.04 **
Constant	−3.26	0.12	0.52	−3.26	−1.14	−3.95	<0.01 **
Model Diagnostics							
Log Likelihood	−274.2						
LR Test (*p*)	<0.01						
AIC	560.4						

** significant at $\alpha = 0.05$ level, + significant at $\alpha = 0.10$ level.

5. Discussion

Researchers that are interested in public perceptions of water reuse often rely on surveys to assess public responses, particularly willingness to drink reclaimed water resources. In our survey, 35% of respondents indicated that they would be willing to drink reclaimed water. Other recent surveys on this topic demonstrate a range of support exists, from 9% support for potable water reuse in Iran [52] to 72% support in Tianjin, China [53]. Our results match the general consensus among other scholars regarding the 'ladder of acceptance' for reclaimed water [14,24,54]. This study finds that the proximity of reclaimed water to human contact has an effect on support for different uses of the water supply, regardless of location. Uses further from human contact, such as industrial processes or irrigation of parks and lawns, receive the highest amount of support from the public, while drinking, cooking, and cleaning receive the least support.

Additionally, our models demonstrate certain characteristics, namely gender, prior knowledge, and length of time in residence, are linked to increased levels of willingness to drink reclaimed water. The influence of gender on willingness to drink reclaimed water has been explored previously. Although not all research finds gender to be a significant factor, some studies have indicated a greater willingness for men to drink reclaimed water [14,16]. Our research supports this finding. The influence of experience and prior knowledge of water reuse on levels of acceptance is likewise a recurring topic within this field. In our study, 87% of respondents reported that they had heard of reclaiming treated wastewater before, which is higher than most other previous studies. Previous knowledge of reclaimed water use varies from one community to another. The reported percentage of respondents with prior knowledge of water reuse ranges from 28% in a study in India [21] (p. 8) to 90% of respondents in

Beijing, China [18] (p. 9702). In the western United States, a study in Oregon found that 75% of survey respondents expressed a familiarity with the term "recycled water" [28] (p. 9). The relatively high level of prior knowledge in the Reno-Sparks communities could be a result of the visibility of non-potable reclaimed water uses, such as irrigation, which have occurred for decades throughout the region [33]. Length of time in residence, however, has not been explored previously and our research is novel in exploring this factor. We demonstrate within Reno-Sparks that with each additional year that a respondent has lived in their current home, the odds of being a willing drinker are reduced by 2%.

The most novel contribution of our research is the connection between self-reported residential location and willingness to drink. Our research focuses on the explicit spatial scale of community types within cities. There are notable differences in responses and perceptions between where within a particular city or region a respondent lives. Underlying values, particularly regarding residential location, appear to be central to public opinions about potable reuse in northern Nevada. The notable finding of our research is that living in a suburban area has a positive and significant influence on willingness to drink reclaimed water and we observe that suburban respondents are more accepting of other reclaimed water applications than urban and rural respondents. Suburban respondents, then, have distinct preferences toward uses of reclaimed water as compared to urban and rural respondents.

An explanation of why suburban respondents are distinct is open to interpretation. Some studies have indicated a link between higher income and increased levels of acceptance for potable reclaimed water; however, there is not consensus on the influence of this factor [14,16]. We did not include any questions related to income levels within the questionnaire. It is conceivable that suburban areas within northern Nevada are comprised of individuals with higher incomes; however, scholars have questioned the previously assumed higher socioeconomic status and income levels of suburban communities in recent decades [55–57]. Future research on this topic may include a survey question about income level to determine whether this factor is linked with willingness to use and drink reclaimed water as well as demonstrate how income affects residential location of respondents.

An alternative explanation for suburban distinctness may lie in the development patterns of the region. In northern Nevada, large-scale development in the past decades has largely been single-family residences and the creation of 'master planned communities', typically categorized as suburban developments. It is conceivable residents of suburban communities were initially attracted to the 'planned' aspect of these developments and the community features present within them. The individuals living here could seek alternative ways to continue their water consumption levels and maintain the typical suburban lifestyle in the desert climate of northern Nevada, including residential landscaping, park facilities, and other water intensive amenities. Indirect potable reuse may be of overall interest to this group to ensure that enough water supply is available to maintain their current consumption patterns.

Commonly urban and suburban individuals are lumped together and rural is considered to be the outlying 'other' (the opposite of urban) and we anticipated that rural respondents in our region would be distinctly less willing to drink reclaimed water when compared to other communities. However, an unexpected result was that rural and urban values are closely aligned (although not overlapping), whereas the suburban values in our study were distinct. There is a clear division between rural, urban, and suburban responses to the questions surrounding acceptable uses for reclaimed water. It is notable that suburban support for all uses is higher than urban or rural support. In fact, a clear hierarchy exists where rural respondents are generally the least supportive of reclaimed water uses, the urban respondents are in the middle, and suburban respondents are the most supportive of reclaimed water uses.

There are some limitations of this study, which include the potential for self-selection bias and the English-only questionnaire. We also note some demographic differences between the respondents' characteristics and those of the rest of the region. Our sample includes a higher percentage of respondents over the age of 65 (46%) as compared to the Reno-Sparks region as a whole (14.6%) [58]. Therefore, the results of this study are more applicable to the older population

of the region, and additional studies will be needed that specifically sample its younger residents. It is noteworthy, though, that this older group of respondents did indicate a relatively high degree of willingness to consider reclaimed water for a variety of applications, at least in the suburban areas. Additionally, on the questionnaire, the respondents were asked to classify their residence in one of three groups: city/urban, countryside/rural or suburban. There is some degree of uncertainty in these findings, too, as it is conceivable that there could be heterogeneity in how respondents classified themselves. However, our study focused on the relationship of local identities and attitudes and preferences towards reclaimed water use. The potential for self-selection bias suggests that participation could have been systematically avoided by certain segments of the population, therefore more comprehensive data collection techniques in future studies may help to supplement and enhance the findings of this study.

Our findings highlight key differences in urban, suburban, and rural attitudes toward reclaimed water that water planners and managers in Reno-Sparks should consider carefully when deliberating on the most socially, environmentally, and economically feasible alternative. Our goal is not to explicitly facilitate greater implementation of potable water reuse. Yet, as alternative water resources become an increasingly enticing option to water scarce municipalities, it is vital for researchers to understand the variety of stakeholders and local identities within a broader community of water users. The purpose of this case study is to underscore the importance of place as one of many key factors that shape public response to water reuse. Certain locations may be more or less agreeable to a potable water reuse scheme. Feasibility assessments prior to a project would benefit from a comprehensive understanding of land use composition and perception of this space by the potential water users. By seeking to understand the complexity of public opinions, we reveal that a previously unexplored factor—perceptions of community type—significantly influences willingness to drink reclaimed water. Classifying landscapes as urban, rural, and suburban based on physical characteristics alone without insight from the residents does not account for perceptions of the occupants. Our findings suggest a more nuanced perspective towards land use classification may be necessary to understand and accommodate public opinion and values within planning decisions for reclaimed water resources.

6. Conclusions

Growing evidence suggests that reusing wastewater for potable or non-potable purposes is becoming a key element of water resource management in cities across the globe. Water planners are looking to greater a utilization of reclaimed water supplies as part of a solution that promises a more sustainable water future. In this study, we illustrate how place-based identities influence public responses to potable water reuse. Our findings suggest that water managers should carefully consider social-spatial differences in public opinion and tailor the water systems to a particular scale of implementation to prevent against public opposition and secure public investments in water infrastructure.

The respondents almost unanimously expressed concern regarding long-term water supplies in northern Nevada; however, it is important to note that there is not a unified, coherent 'public opinion' where reclaimed water is concerned. We find that different underlying values, particularly regarding residential location (urban, suburban, or rural), are central to public opinions about potable reuse, and that suburban respondents distinctly express higher levels of willingness to consider drinking reclaimed water and seeing it applied in various other ways. These results underscore the importance of socio-spatial factors while broadening our understanding of the range of variables that impact public responses to potable reuse. Specifically, we find that suburban residents are more willing to accept the reclaimed water for a range of potential uses—including drinking.

Our results advance current knowledge on the subject by providing empirical evidence of greater social-spatial variation than has been previously explored. Most importantly, these results provide empirical evidence of a previously unidentified influential factor relating to community attitudes of reclaimed water: residential location. Other studies have examined public perceptions, and then

compared reclaimed water acceptance across cities or countries. This is the first case study to examine the relationship between public perceptions and the spatial scale of community types within cities, which is critically important as municipal water reuse becomes an increasingly popular water management strategy.

Supplementary Materials: The questionnaire is available online at http://www.mdpi.com/2071-1050/11/3/564/s1.

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