KNOWLEDGE, PERCEPTIONS AND UNDERSTANDING OF GROUNDWATER AND GROUNDWATER ISSUES A TEXAS SURVEY: 2017

The Meadows Center for Water and the Environment
July 2018

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Jenna Walker, M.A.Geo., Contributor

The Meadows Center
for Water and the Environment
Texas State University

MEMBER THE TEXAS STATE UNIVERSITY SYSTEM

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Performing Agency:

Texas State University
Department of Finance and Economics in the McCoy College of Business, and
The Meadows Center for Water and the Environment

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EXECUTIVE SUMMARY

The purpose of this study was to answer this question posed by The Meadows Center: What are Texas residents' knowledge, perceptions and understanding of groundwater? Questions posed in the online and print versions of the survey also asked about respondents' perceptions of current and future groundwater availability, their perceptions of what impairs groundwater quality, the impact of certain land uses, practices and pollutants on groundwater quality, and their sources of drinking water. Respondents were asked about the priorities they placed on groundwater use in times of decreased supply of, or increased demand on groundwater. Because groundwater conservation districts have the authority to manage and oversee groundwater quality and quantity, the survey culminated with a question asking if respondents were aware of the existence of these districts.

Groundwater Knowledge, Perceptions and Understanding

- 64% of online survey and 74% of mail survey respondents agreed as true that groundwater in Texas can be best described as pooled water in underground formations. Online survey respondents (97%) and mail survey respondents (90%) see as true the source of groundwater as the seeping into the ground of rain and other water on the surface.

Perceptions of Groundwater Availability

- More online respondents (95%) believe, in general, that groundwater is plentiful and will always be available for human use than not. When mail survey respondents were given a Don't Know option, about 14% chose this option. 79% responded that groundwater is plentiful and will always be available for human use while 7% did not.

- More online and mail survey respondents agreed that there would be enough groundwater to meet current needs at the county level than those who disagreed. More respondents disagreed that there would be enough groundwater to meet needs over 25 years at the county and state level than agreed.

- A notable percentage (25% or more) of mail survey respondents chose 'Don't Know' when given this option as a response to the question about the availability of groundwater to meet future needs over 25 years at the county or state level, or current needs at the state level.

Perceptions of Groundwater Quality

- Industrial areas and cities, septic tanks and waste are the land uses and practices that are rated as having the highest detrimental effect on groundwater quality from both online and mail survey takers. Septic tanks, ranch/farm lands also received high ratings, although the actual ratings differed depending on whether the survey was taken online or in print form. Gasoline or Oil and Industrial and Household Uses received high ratings as pollutants deemed to have the most negative or detrimental impact on groundwater quality, followed closely by fertilizers, herbicides, and insecticides.

Source(s) of Drinking Water

- The public supply of drinking water from surface water and groundwater serve as a source of drinking water for the highest percentage of online respondents. Mail survey respondents derive their main source of drinking water from a private well.

- A notable percentage of respondents reported bottled water as a source of drinking water, although a higher percentage of mail survey respondents used this as a source of drinking water than online respondents.

Groundwater Allocation in Times of Scarcity and Priority of Use

- Building underground storage space for water supply and buying or transporting water from one location to another to preserve groundwater availability in the future was ranked with lower priorities by both online and mail survey respondents, although the rankings differed. Limiting the growth of cities seemed to polarize respondents.
- For both types of survey takers, a high percentage ranked the responsibility of households to conserve the use of groundwater as either Priority 1 or 2.
- Restructuring rates and using treated wastewater inside or outside the home received lower priority ratings, although online and mail survey takers rated them differently. A higher percentage of respondents rated using treated wastewater outside the home on lawns or landscapes as an option to preserve groundwater availability than using treated wastewater within the home.
- Respondents make a distinction between allocating groundwater for the natural environment (fish, wildlife, habitat) and for natural resource management (instream and wetland). There is more of a uniformity of rankings for the natural environment between the sample groups than there is for natural resource management.

Knowledge of and Interaction with Groundwater Management

- 90% of online respondents and 70% of mail survey respondents were aware of the existence of groundwater conservation districts.

1. INTRODUCTION

Between 2015 and 2017, Texas cities with a population exceeding 50,000 counted amongst the fastest growing in the United States (Ura & Daniel, 2017). With that growth came increasing demand from all sectors of the economy for surface water and groundwater. A statewide drought in 2011 stressed the supplies of many natural sources of water including the Pedernales, Brazos, and Trinity Rivers.

Against this backdrop, The Meadows Center for Water and the Environment (The Meadows Center) in San Marcos, Texas conducted a two-phase research study into the connection between surface water and groundwater in Central Texas, and the sustainability of their supply as determined by the hydrogeology of regional aquifers, rivers, watersheds, management and conservation efforts.

In the second phase, The Meadows Center desired to collect data that would support water conservation efforts and ensure the sustainability of its supply. In addition, The Meadows Center desired to support research that would allow it and its research partners to engage in outreach and educational activities and to inform landowner management activities. To this end, The Meadows Center requested that Dr. Joni Charles conduct an online survey of Texas residents' perceptions and understanding of groundwater. Additional questions surveyed respondents' understanding, knowledge and opinions of the local governance process by which groundwater policy is implemented. Users' knowledge of groundwater – its origins, availability, future availability, uses and the governance process are critical to the effectiveness of state and local conservation, preservation, and protection efforts. In order to focus the report on the primary objectives of The Meadows Center, the content of this document presents the data collected on Texas residents' perceptions and understanding of groundwater and knowledge of the existence of groundwater conservation districts.

2. LITERATURE REVIEW

In 2005, a mailed survey of public attitudes, beliefs, and perceptions about water was conducted (Boelstorff, McFarland, & Boleman, 2005) with support from the United States Department of Agriculture (USDA) and assistance from The University of Idaho and the Texas AgriLife Extension Service. Survey respondents came from a randomly drawn sample of Texas residents who were asked about their perceptions of, and concerns about, drinking water, surface water and groundwater quality, and water-related activities (Boelstorff et al., 2005). Another Texas-based survey (Dickson, Ver Duin, Ruggiere, & Glass, 2005) specific to North Texas was conducted by telephone to a random sample of Denton and Denton county residents. The focus and objectives of this survey were similar to the first but also included questions about knowledge and sources of water pollution at the municipal and county level, responsibility for water quality, and market-based solutions to water problems.

There have been other surveys of water users' behaviors, attitudes, beliefs or opinions. Some of them were conducted in specific regions in the United States (Edwards, 2013; Fitts et al., 2010; Hu & Morton, 2011; Pritchett et al., 2009) and others were nation-wide (Hu, Morton, & Mahler, 2011). The Fitts et al. study included a question about the respondent's choice of water-allocation mechanisms. Another study (Holsman, Linderman, Krueger, & Suvedi, 2000) was particularly helpful as a source of questions and providing question structure for this study. The Pritchett et al. study was the source for the structure of some of the demographic questions contained in this report.

Governance issues were not a prominent part of most of these surveys, but it was foremost in the Edwards survey. The Hu and Morton study notes that changing practices means engaging citizens in the deliberative

process so that their values and attitudes are better understood. Respondents to the Fitts et al. survey were local elected officials and water managers, so survey results revealed the role of tensions between levels of government as decisions about water are made.

3. METHOD

3.1 Study Area, Scope, and Launch

The survey was developed using Qualtrics software and made available on the Internet by a third-party mail system from February 2 – March 3, 2017, or by mail from Feb. 6 - March 27. Potential participants were promised anonymity and ballot-box stuffing was prevented by using the Qualtrics option of assigning 'a unique, one-time use link for each participant'. The survey could only be taken once, but the link could be shared with other potential respondents. The population of interest for the Internet survey was originally water users in Central Texas, but the link to the survey on the cooperating institutions' websites resulted in survey responses from across the state of Texas.

Online survey participants were solicited from email contact lists obtained from Gillespie and Blanco County Extension Agencies, both of which are in central Texas. Additional participants were solicited from contacts lists of the Hill Country Alliance which is a non-profit organization in central Texas. Two organizations agreed to post the survey link on their website. These two organizations were The Meadows Center for Water and the Environment, a research institute on the campus of Texas State University in San Marcos, Texas, and the Hill Country Underground Water Conservation District, an entity entrusted with management and regulatory oversight of groundwater in their local jurisdiction. Participants recruited through the link to this survey constituted a convenience sample for this survey. Therefore, these survey participants were stakeholders with a greater interest in water issues and/or knowledge and understanding of groundwater and groundwater governance than members of the general public.

Printed surveys were mailed to a total of 500 Central Texas residents – 250 each from Blanco and Gillespie counties. In each county addresses were mapped out. A random number table and Citizen Scientist Monitor IDs were used to identify 125 city and 125 non-city addresses. Pre-paid return envelopes accompanied all mailed surveys. The sampling format of the internet and print surveys reflect access and funding constraints to a broader base of email recipients and physical addresses.

In summary, the online and mail sample of respondents constituted a low cost, convenience sample of interested stakeholders and, as such, this report should be considered exploratory.

3.2 Questionnaire Design

The objective of administering the survey was to use both quantitative and qualitative analysis to gauge the understanding and perceptions of groundwater issues, and of groundwater governance in Texas. Questions covered general knowledge about groundwater, its source and aquifer boundaries, causes of compromised groundwater quality, perceptions of the availability of groundwater at the state and local level, preferences for sources of drinking water, and priorities for allocation of groundwater. Earlier drafts of the survey questions and a pilot test of the survey were circulated to selected water professionals in the non-profit sector, industry, the private sector, and government to help clarify definitions, terminology, and to provide overall feedback on question order, validity, and composition.

There were 26 questions consisting of open-ended and closed-ended questions. The survey was designed to

take no more than twenty minutes. In total, there were 341 who started the Internet survey. 265 respondents completed the survey, meaning surveys that were closed, submitted by the due date and therefore recorded, whether partially or fully completed (78% completion rate).

47 three-page mailed surveys were completed and returned - a response rate of 9.4%. Eight surveys were returned unopened. No incentives were provided to survey participants due to funding constraints.

3.3 Question Items

General knowledge about groundwater, its aquifer source, aquifer boundaries, sources of drinking water, and perceptions about groundwater abundance were the focus of five survey questions. Response options were True/False and Agree/Disagree/Don't Know. Respondents were required to write in the name of the aquifer that served as the source of their drinking water if they knew it.

Respondents were asked two questions to rate perceived causes of groundwater pollution. Online respondents to these two questions were given a slider bar to drag along a continuous scale to indicate their rating of these causes; mail survey respondents were given discrete options. One question asked respondents to Agree/Disagree/Don't Know to a series of four questions about groundwater availability, currently and in the future, at the state and local level.

Two questions consisted of a series of seven choices for survey participants to rank order. One question inquired about allocated uses of groundwater in cases of increased demand or decreased supply. The other question was about planning for future sources of groundwater in case of limited availability.

Groundwater management, groundwater governance and the institutions responsible for both were the subject of an additional set of questions. In Texas, groundwater conservation districts (GCDs) play an important role in groundwater conservation. One question with Yes/No response options was given to learn about the respondent's knowledge of the existence of GCDs.

Finally, there were seven socio-economic/demographic questions: property-ownership, type of property, amount of property held, age, race/ethnic origin, household income, and zip code.

3.4 Reporting of Survey Results

Since the majority of respondents to the survey were selected from a convenience sample, no sampling errors have been calculated and no statements of sampling error or statistical significance have been made. No inferences should be drawn about the larger population from which the sample was drawn and the results only pertain to the sample represented in this report. Descriptive statistics (measures of frequency, central tendency, and variation) are reported instead. No non-parametric tests were applied to test for significant differences between online survey takers and the central Texas respondents who were mailed surveys, since the number of respondents was so different.

The last question of the survey allowed respondents to share comments about how groundwater is managed in their district. These comments are beyond the scope and original mission of the research but qualitative analysis of these comments can provide a basis for future research efforts.

Survey results for online responses are shown in figures; 'A' versions of each table show online responses to each question, 'B' versions show mailed survey responses. Data tables are used when the percentage of responses to the question are too small to be shown on the chart. Percentages reported represent recorded responses to a question. Not all survey participants responded to every question. Online and mail survey participants were able

to skip questions because of branch, display, or skip logic[1] built into the structure of the questionnaire. Online, if questions were omitted inadvertently, they were encouraged to return to the question to answer it. For both online and mailed surveys, complete responses include respondents who chose to skip questions that were not required.

4. DESCRIPTIVE NARRATIVE OF RESULTS AND FINDINGS

4.1 Summary of demographic findings[2]

Online, 314 people chose to answer the question on income; 37 answered this question on the mailed survey. A majority of the responses chose the income category of $100,000 or more (Figures 1A and 1B). Some respondents chose not to answer this question. There may be several reasons for this. A simple reason may simply be that people are reluctant to disclose their income. Another reason is that household income is derived from several sources and from multiple people within a household. Respondents may feel an additional burden to answer this question accurately.

The small number of non-white participants is consistent with two knowledge/perception studies noted earlier (Dickson et al., 2005; Holsman et al., 2000). 315 people responded to the online question on race and ethnicity. White/Anglo/Caucasian respondents comprised almost 86% of these respondents, while a smaller percentage (75.61%) indicated this category as their ethnic origin on the mailed surveys. Figures 2A and 2B show that there was a small (5.40% online survey and 2.44% mailed survey) representation of Hispanic/Latino respondents, but no respondents identified themselves as Black/African-American.

The same number of people answered the online question on age (Figure 3A and 3B). There were 39 responses to this question on the mailed survey. Just over 70% of online respondents are 45 years of age and older; while, just over 85% of the mailed survey respondents were 45 years of age and older. Figure 4A shows that there were slightly more online respondents to the homeownership question than in the previous question, with 90% of 320 respondents living in single-family homes, and 86% describing themselves as property owners. Almost 46% of the property owned is less than a half-acre, while just about 25% of property owned is between a half-acre and 5 acres (Figure 6A). 85.37 % of 37 who responded to this question on the mailed survey reported living in a single-family home (Figure 4B); 87.8% of 41 mail survey respondents indicated that they were property owners (Figure 5B). A smaller percentage of this sample, compared to online respondents, owned less than ½ acre – 7.31% of the 38 who responded to this question. 14.63% of mail survey respondents owned between ½ and 5 acres (Figure 6B).

[1] There are several types of logic which can be built into a questionnaire as described by Qualtrics documentation. Skip Logic is a feature of the questionnaire that directs the survey-taker to a future point later in the questionnaire or to the end if the survey-taker decides not to participate. Branch Logic directs survey-takers to a different batch or block of questions depending on how a question is answered. Display Logic displays a set of questions conditional on a response or criteria met by the survey-taker.

[2] Figures show the results from the online version (A) and mailed version (B)

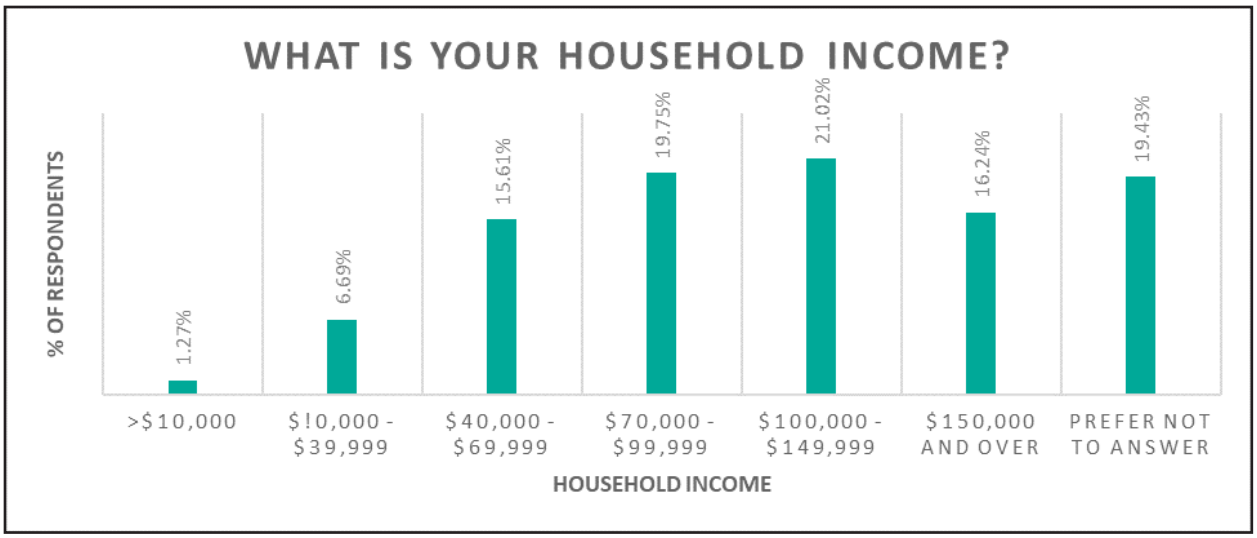


Figure 1A. Household Income Results for Online Survey

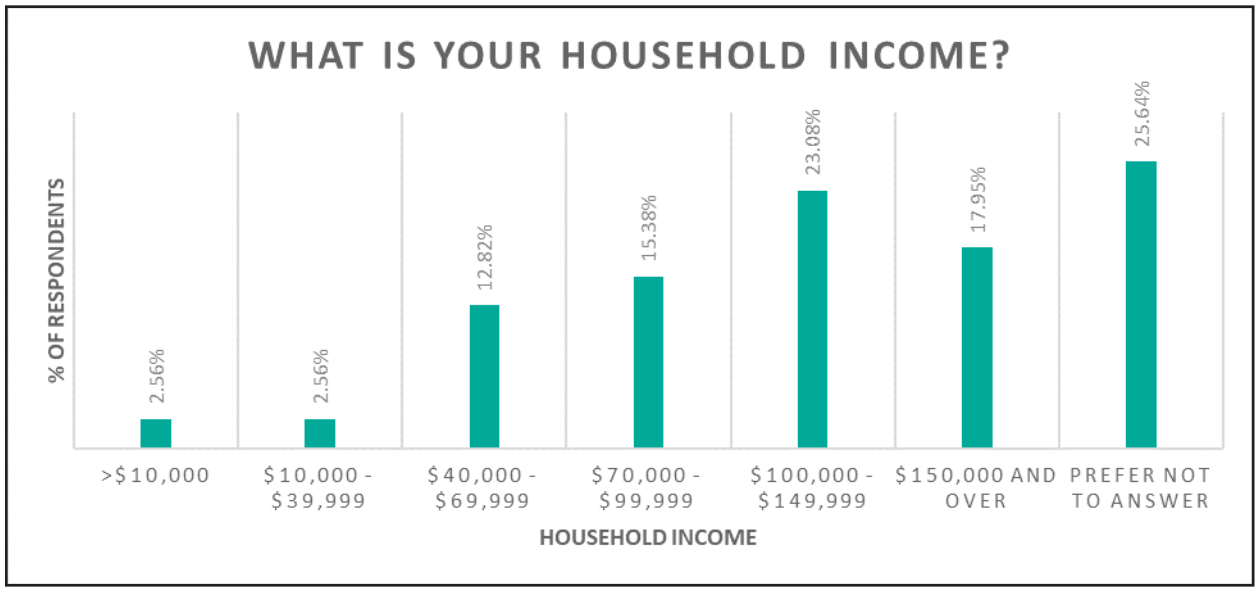


Figure 1B. Household Income Results for Mailed Survey

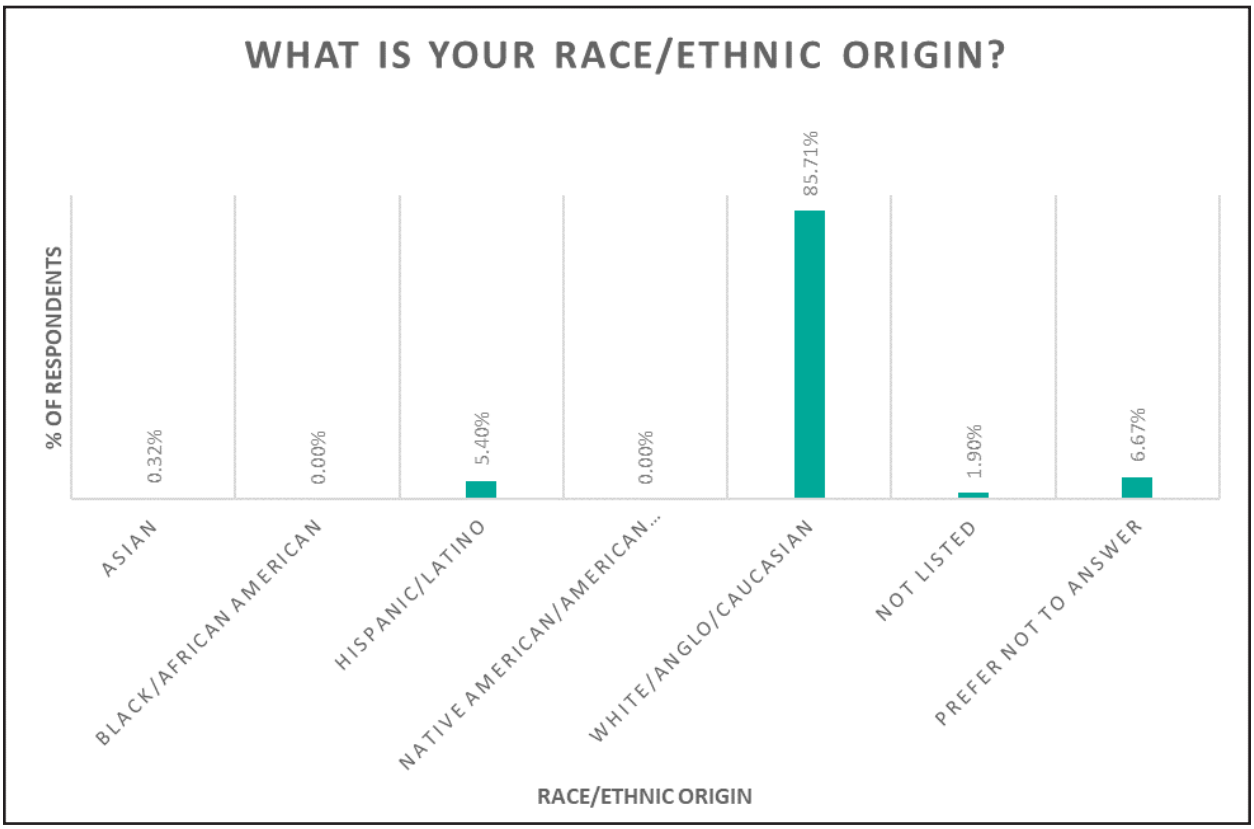


Figure 2A. Race/Ethnic Origin Results for Online Survey

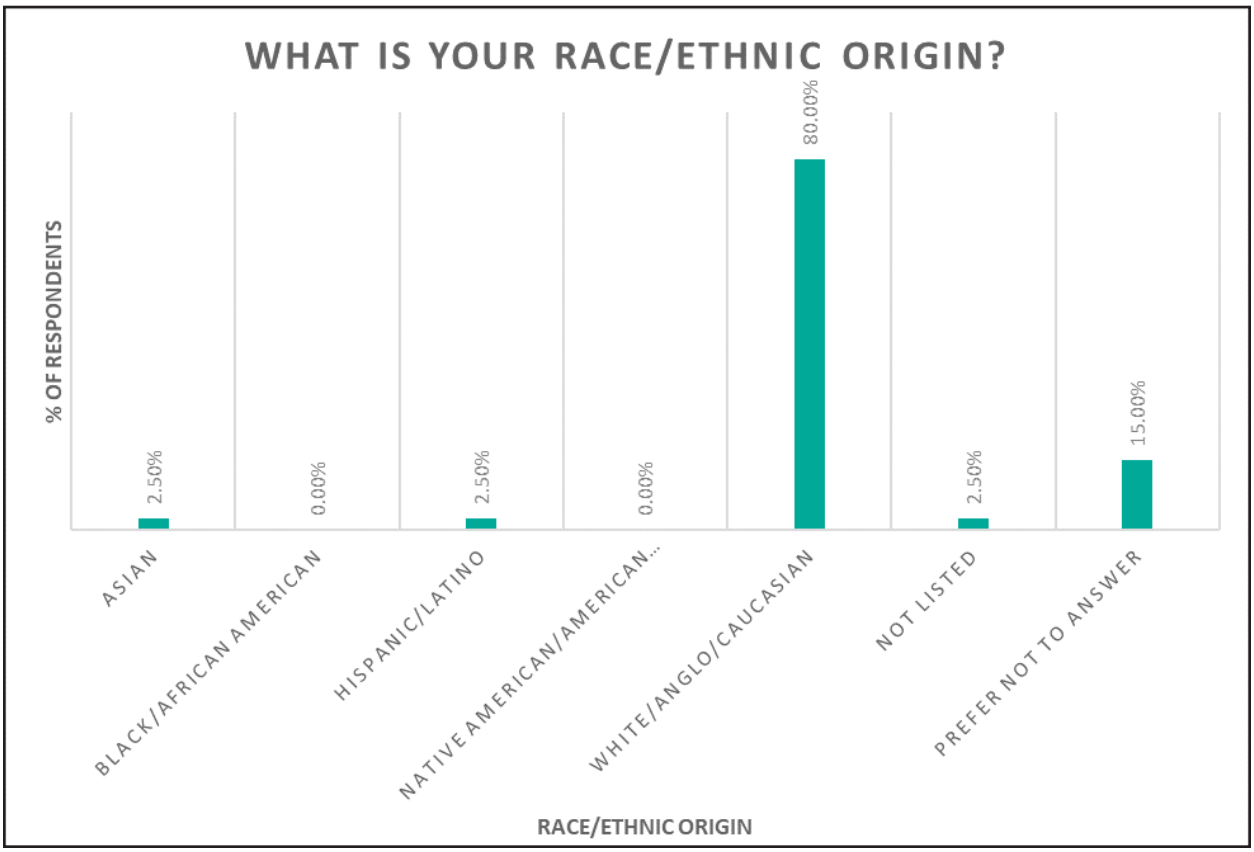


Figure 2B. Race/Ethnic Origin Results for Mailed Survey

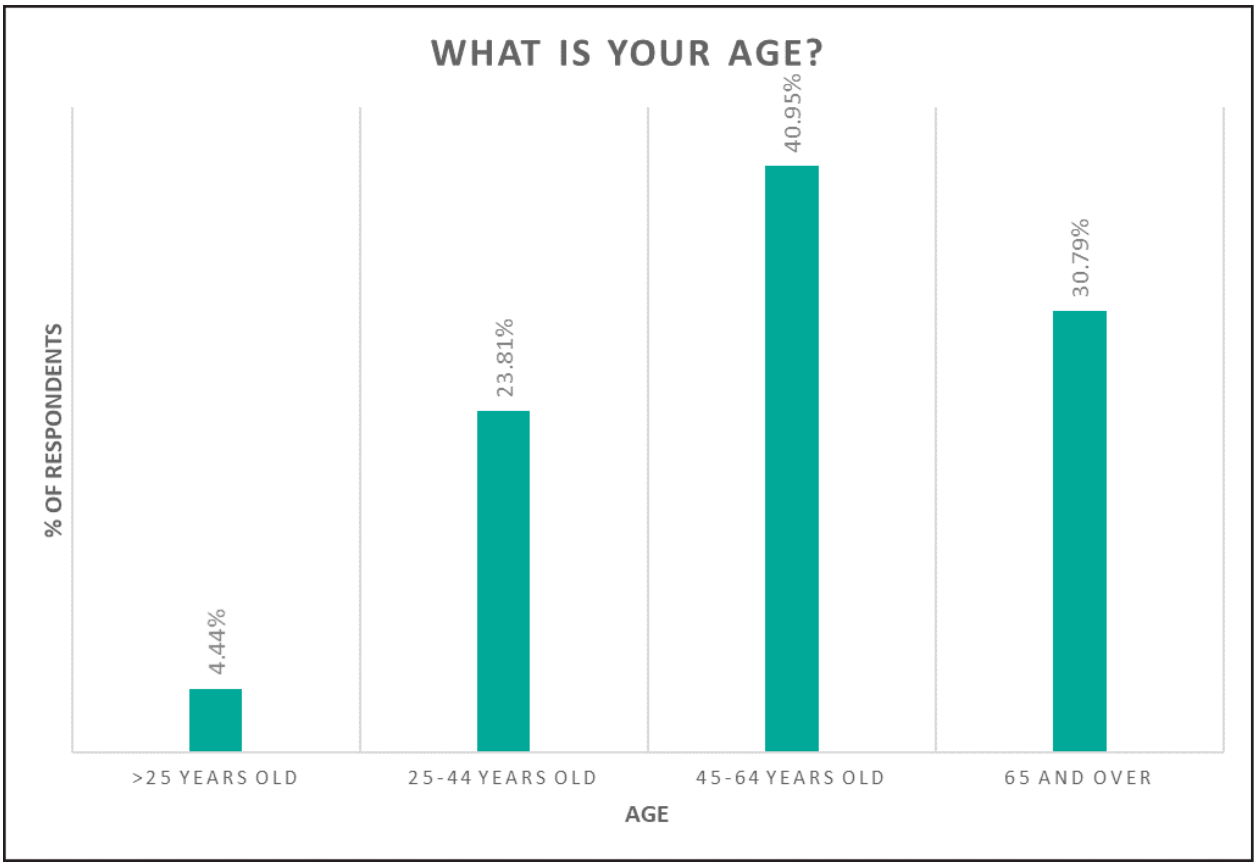


Figure 3A. Age Results for Online Survey

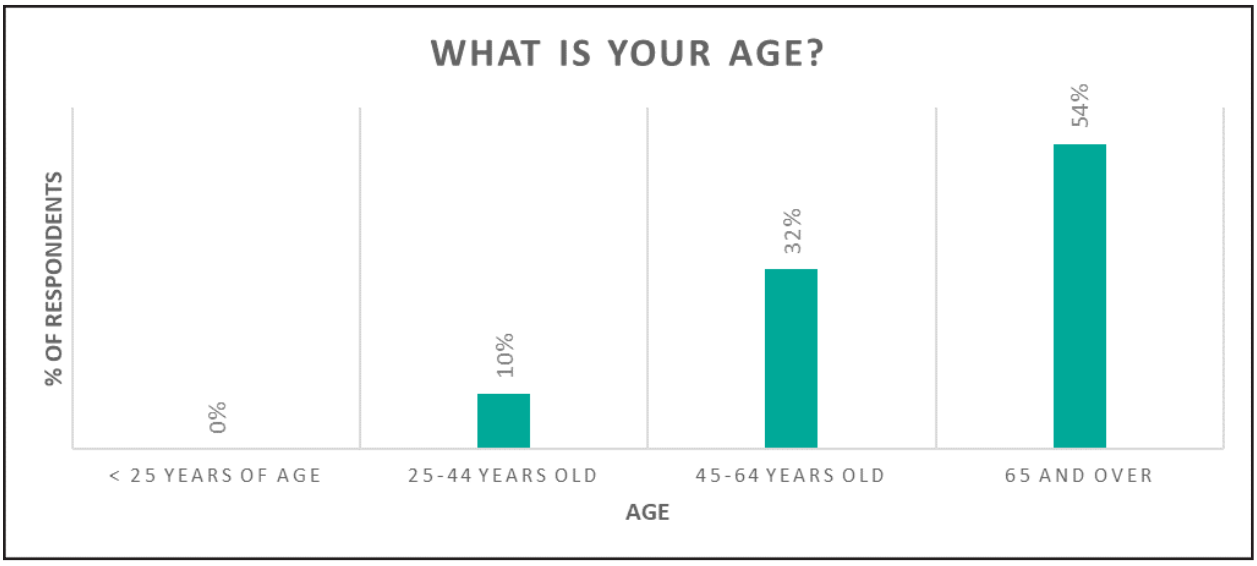


Figure 3B. Age Results for Mailed Survey

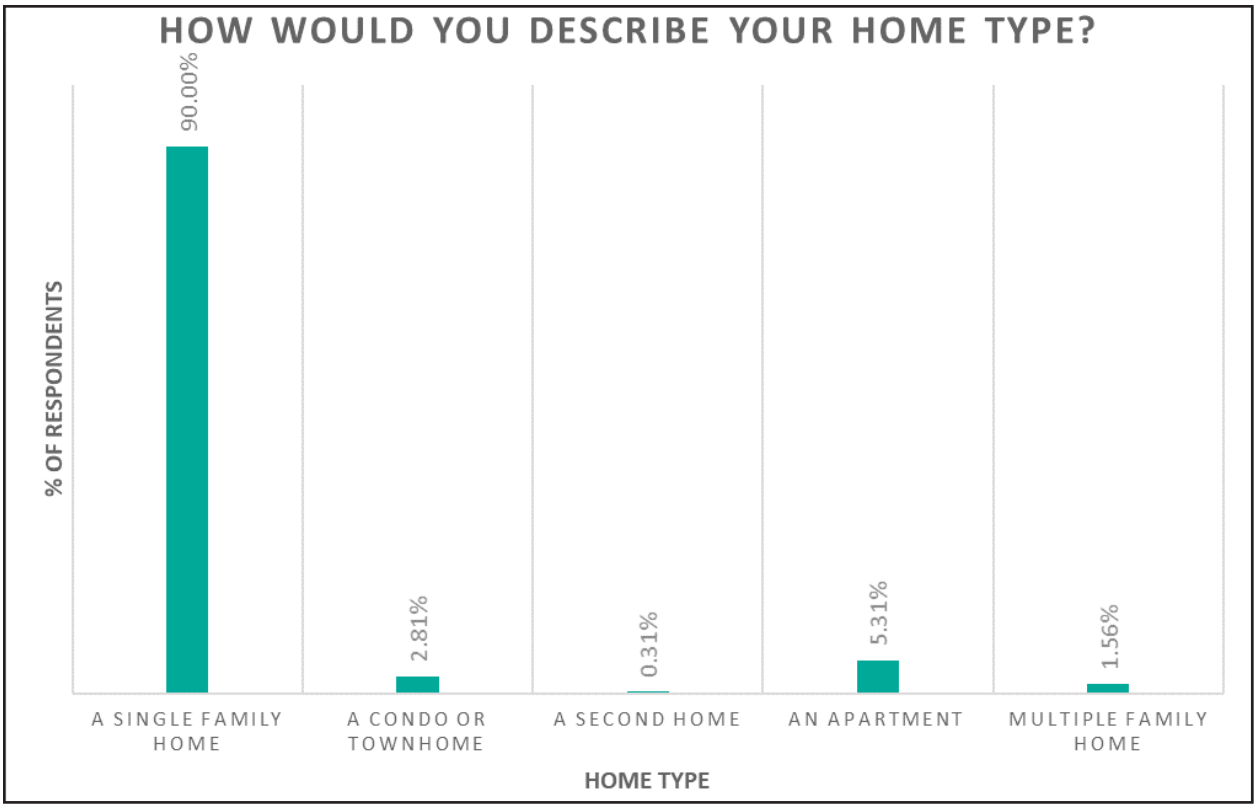


Figure 4A. Home Type Results for Online Survey

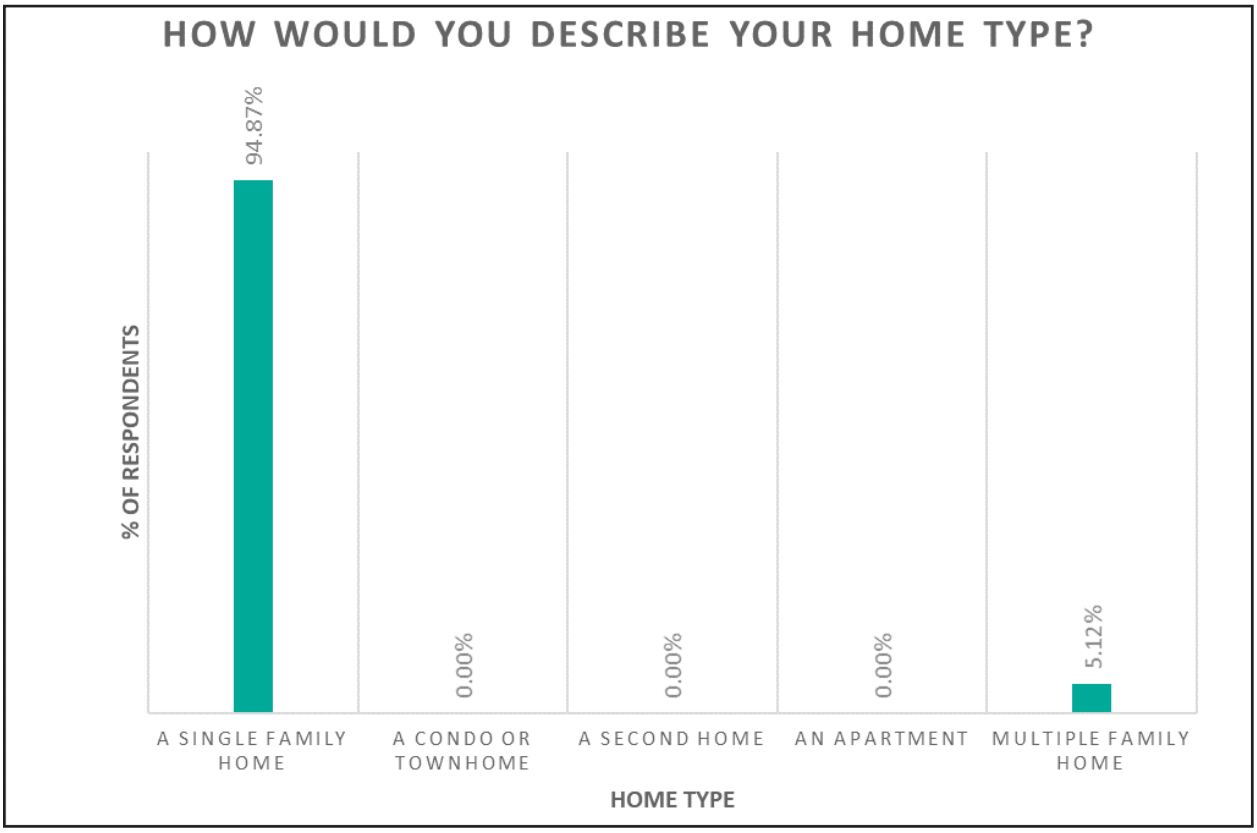


Figure 4B. Home Type Results for Mailed Survey

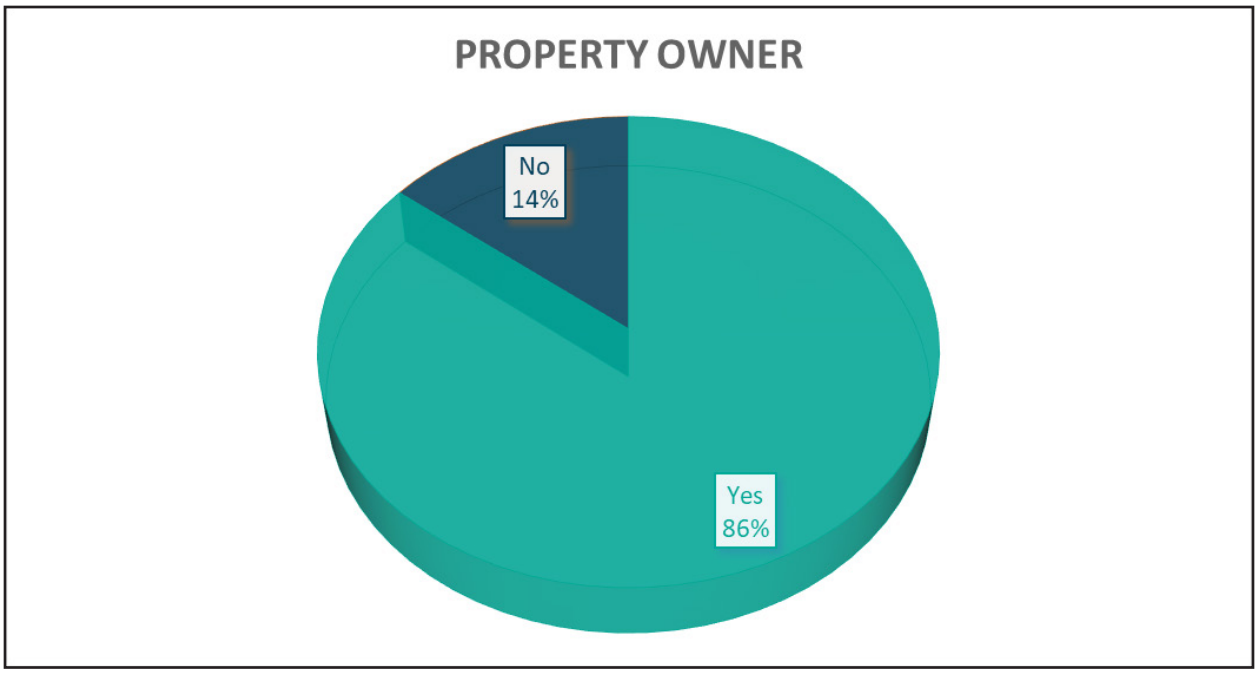


Figure 5A. Property Owner Results for Online Survey

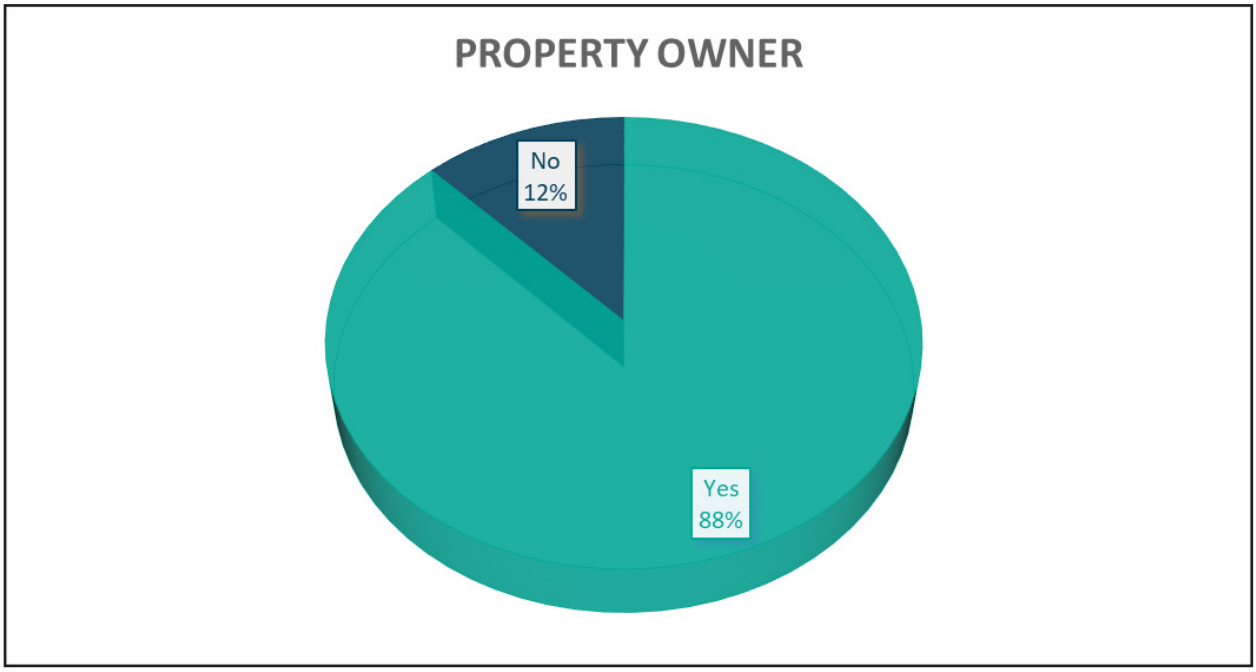


Figure 5B. Property Owner Results for Mailed Survey

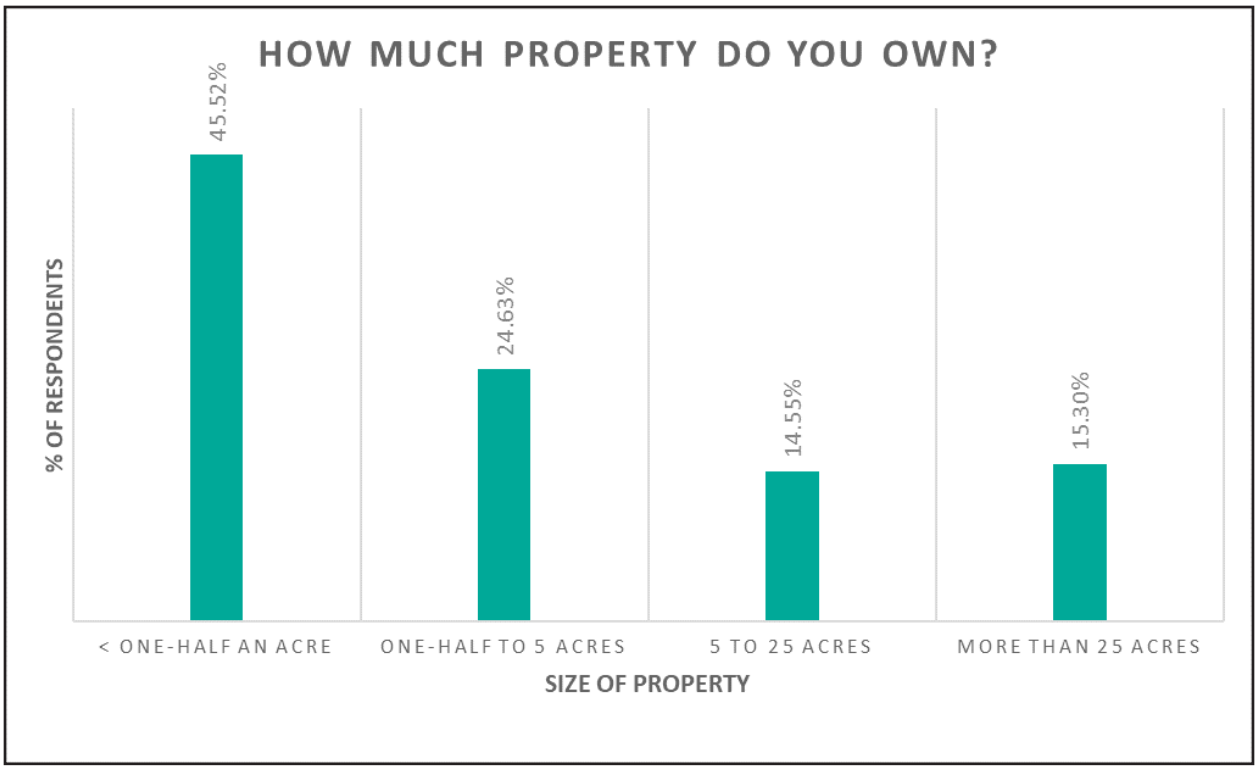


Figure 6A. Property Size Results for Online Survey

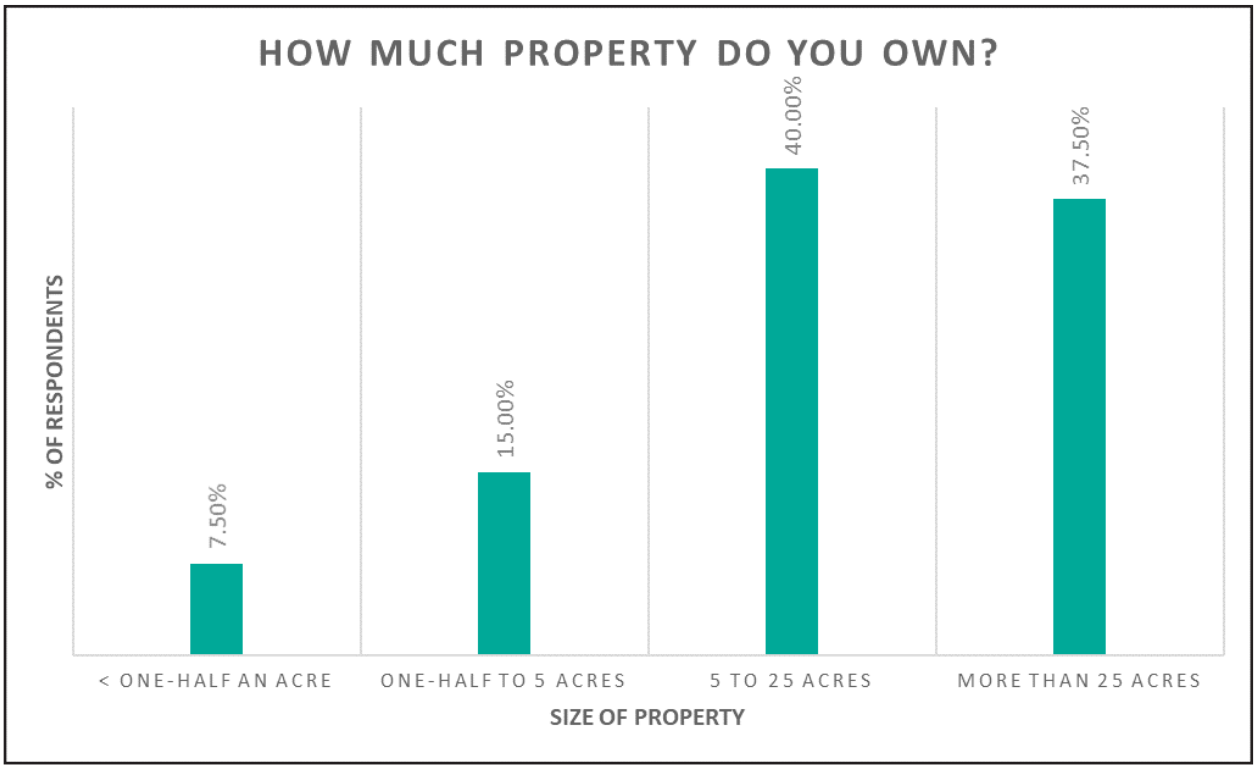


Figure 6B. Property Size Results for Mailed Survey

4.2 Represented Regions by County (Total County Count = 87; 50 Urban, 37 Rural)

Figure 7A shows the regions represented by the zip codes of online survey respondents. There was almost equal representation from East Texas, Central Texas, and South Texas[3]. There were 18 East Texas counties, 18 Central Texas counties and 17 South Texas counties represented from the completed internet surveys. The 18 East Texas counties were San Jacinto, Cherokee, Cass, Morris, Harrison, Gregg, Upshur, Red River, Lamar, Henderson, Anderson, Van Zandt, Marion, Orange, Newton, Tyler, Smith, and Rusk. The 18 Central Texas counties were Hays, Caldwell, Williamson, Travis, Bell, Blanco, McLennan, Burnet, Brazos, Bosque, Freestone, Llano, Coryell, Lampasas, Milam, Burleson, Mills, and Robertson. The 17 South Texas counties were Comal, Guadalupe, Kendall, Bexar, Nueces, Gillespie, Kerr, Cameron, Jackson, Real (rural, border), Edwards, Victoria, Bandera, Medina, San Patricio, Aransas, and Val Verde. Table 1 shows the urban-rural designation of each county.

North Texas and West Texas were represented by 15 and 13 counties, respectively. North Texas counties were Hunt, Johnson, Dallas, Ellis, Denton, Collin, Kaufman, Rockwall, Grayson, Navarro, Wichita, Archer, Parker, Hood. West Texas counties were Lubbock, Howard, Borden, Glasscock, Sterling, Mason, Menard, Pecos, McCulloch, Reeves, Brewster, Kimble, Taylor.

There were five Gulf counties: Harris, Galveston, Liberty, Montgomery, Fort Bend, and one Panhandle county: Randall.

Zip code responses were open-ended, and six responses were not included either because the zip code provided was not a valid Texas zip code, the zip code provided was outside the state of Texas, or the zip code was incompletely, or not filled out.

Figure 7B shows the regions represented by zip codes of respondents who responded to the mailed version of the survey. The predominance of respondents wrote in zip codes that came from central Texas. Zip codes of 17 central Texas counties were provided, and six each of South and South/Central Counties (the zip code provided came from cities that could be in areas of a county in South Texas and counties in either South or Central Texas. There were two East Texas counties: Harris, and Upshur/Gregg. 17 Central Texas county zip codes were recorded, and they came from Blanco, Comal, Travis, Blanco, Hays and Llano. South Texas counties were Bexar, Gillespie, Kerr, Kendall, and Atascosa.

There was no representation from North Texas or Panhandle counties. The four West Texas counties were El Paso, Taylor, Kimble, and Jones. The sole Gulf represented was Galveston County. One zip code in the returned mailed surveys was outside of the state of Texas and seven respondents did not complete the zip code question.

[3] Counties, regions of Texas, and the designation of urban-rural designation can be found using the following links: http://www.texascounties.net/statistics/regions.htm and https://www.dshs.texas.gov/chs/hprc/counties.shtm. Each region does not contain the same number of counties.

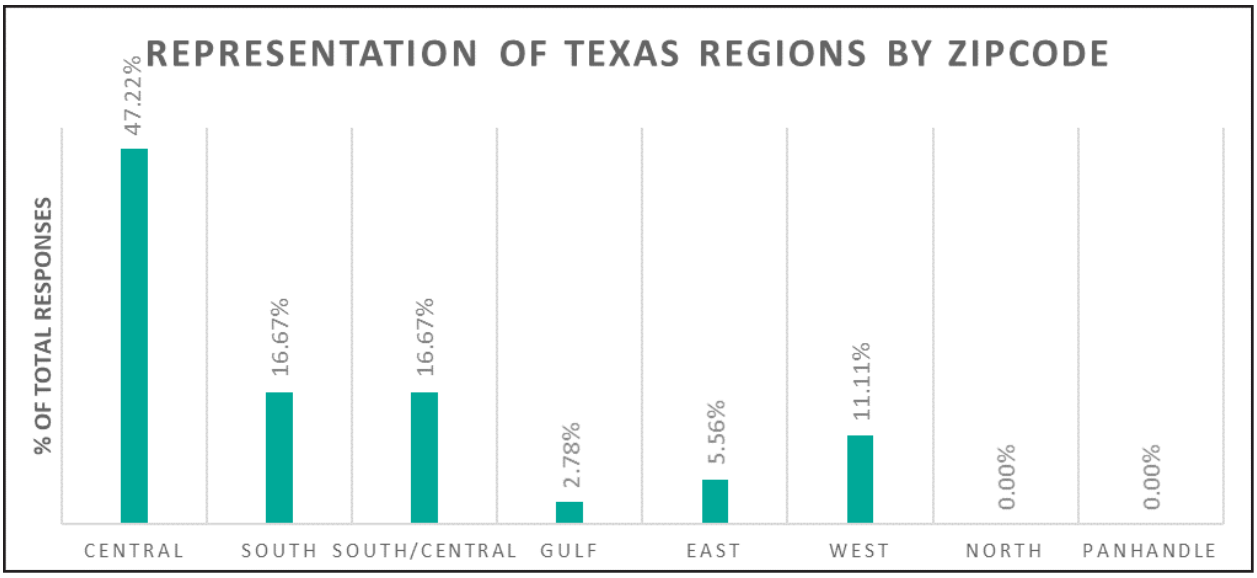


Figure 7B. Zip Code Results for Mailed Survey

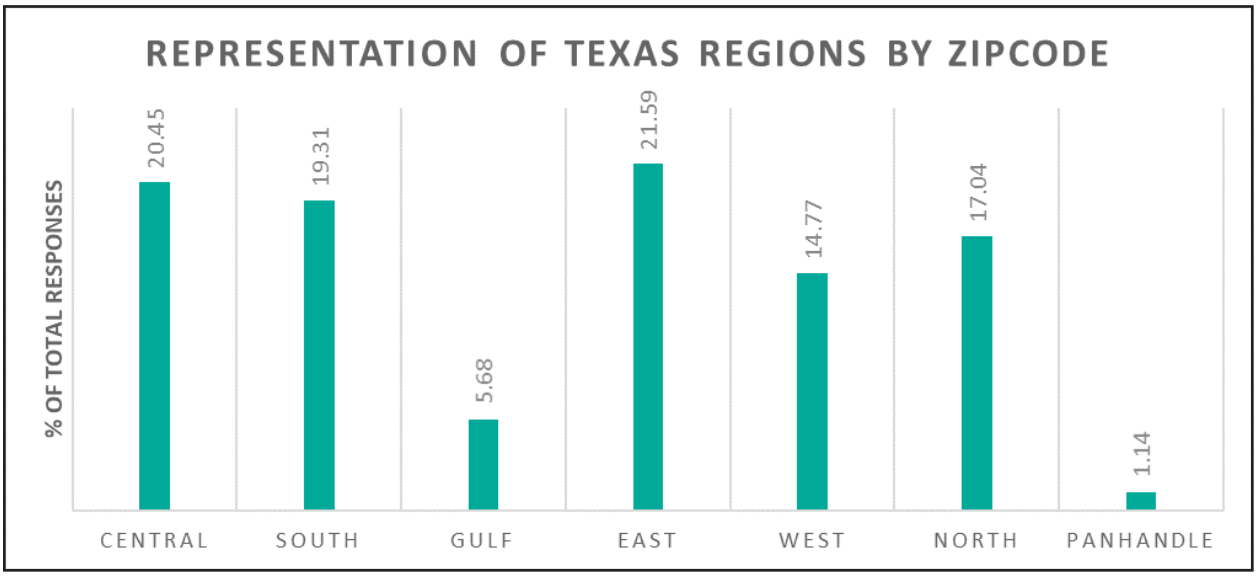


Figure 7A. Zip Code Results for Online Survey

Table 1. Urban-Rural Designation for Each County

County	Classification	County	Classification
Anderson	Rural	Kimble	Rural
Aransas	Urban	Lamar	Rural
Archer	Urban	Lampasas	Urban
Bandera	Urban	Liberty	Urban
Bell	Urban	Llano	Rural
Bexar	Urban	Lubbock	Urban

Table 1. Continued Urban-Rural Designation for Each County

County	Classification	County	Classification
Blanco	Rural	Marion	Rural
Borden	Rural	Mason	Rural
Bosque	Rural	McCulloch	Rural
Brazos	Urban	McLennan	Urban
Brewster	Rural	Medina	Urban
Burleson	Urban	Menard	Rural
Burnet	Rural	Milam	Rural
Caldwell	Urban	Mills	Rural
Cameron	Urban	Montgomery	Urban
Cass	Rural	Morris	Rural
Cherokee	Rural	Navarro	Rural
Collin	Urban	Newton	Urban
Comal	Urban	Nueces	urban
Coryell	Rural	Orange	Urban
Dallas	Urban	Parker	Urban
Denton	Urban	Pecos	Rural
Edwards	Rural	Randall	Urban
Ellis	Urban	Real	Rural, border
Fort Bend	Urban	Red River	Rural
Freestone	Rural	Reeves	Rural
Galveston	Urban	Robertson	Urban
Gillespie	Rural	Rockwall	Urban
Glasscock	Rural	Rusk	Urban
Grayson	Urban	San Jacinto	Rural
Gregg	Urban	San Patricio	Urban
Guadalupe	Urban	Smith	Urban
Harris	Urban	Sterling	Rural
Harrison	Rural	Tarrant	Urban
Hays	Urban	Taylor	Urban
Henderson	Rural	Travis	Urban
Hood	Urban	Tyler	Rural
Howard	Rural	Upshur	Urban
Hunt	Urban	Val Verde	Rural, border
Jackson	Rural	Van Zandt	Rural
Johnson	Urban	Victoria	Urban
Kaufman	Urban	Wichita	Urban
Kendall	Urban	Williamson	Urban
Kerr	Rural		

5. GROUNDWATER KNOWLEDGE, PERCEPTIONS AND UNDERSTANDING

5.1 Groundwater in Texas can be best described as pooled water in underground formations.

This statement was presented to respondents as a way of assessing their understanding of the location and nature of groundwater (Figure 8). The definition itself is a more succinct description of groundwater as 'pooled water in underground rock formations'. While the majority of 'True' responses received is interpreted as indication that respondents do understand and perceive of groundwater correctly, it should be noted that the 36% who considered the statement as false might have viewed the statement as inferior to what they perceived as a more accurate definition of groundwater.

Almost all (96.4%) respondents knew that the source of underground water was from rain and surface water (Figure 9). Only eight people responded to the question that asked if they knew which aquifer was the source of their groundwater; seven of those eight named the Trinity (1), Edwards (2), Edwards and Trinity (1), or Edwards-Trinity (3) Aquifers as the source. One respondent to this question admitted not knowing which aquifer was the source of their groundwater. Aquifer boundaries do not conform to political or geographical boundaries, so it is not surprising that respondents are not aware of the aquifer that supplies their groundwater, and so may have chosen not to indicate this lack of knowledge. The lack of responses to this question shows that knowledge about how groundwater is formed and that it is stored underground is divorced from specific knowledge of the aquifer responsible for supplying that groundwater. However, one insight gained from answers (or the lack of answers) to this question is that coordinated educational efforts across groundwater conservation districts is necessary to ensure that area residents link their academic knowledge about groundwater to a watershed perspective if groundwater conservation efforts are to be effective.

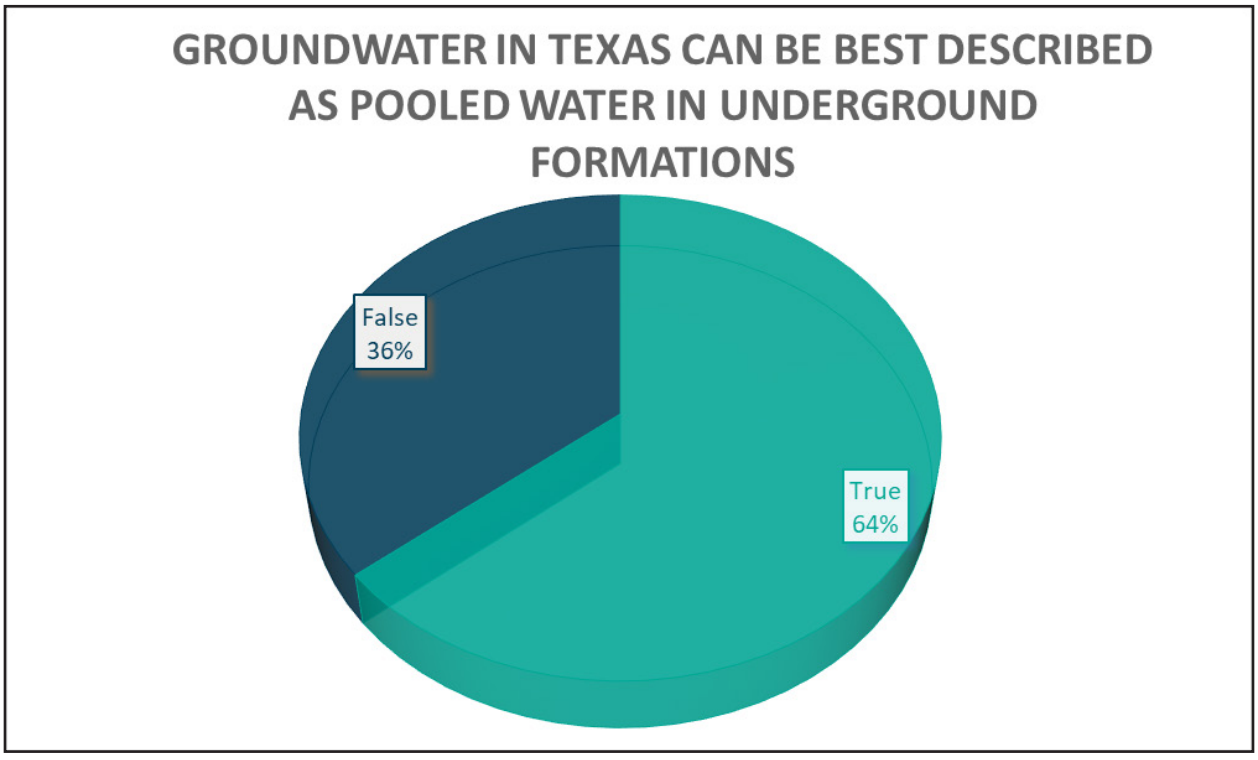


Figure 8A. Location and Nature of Groundwater Results for Online Survey

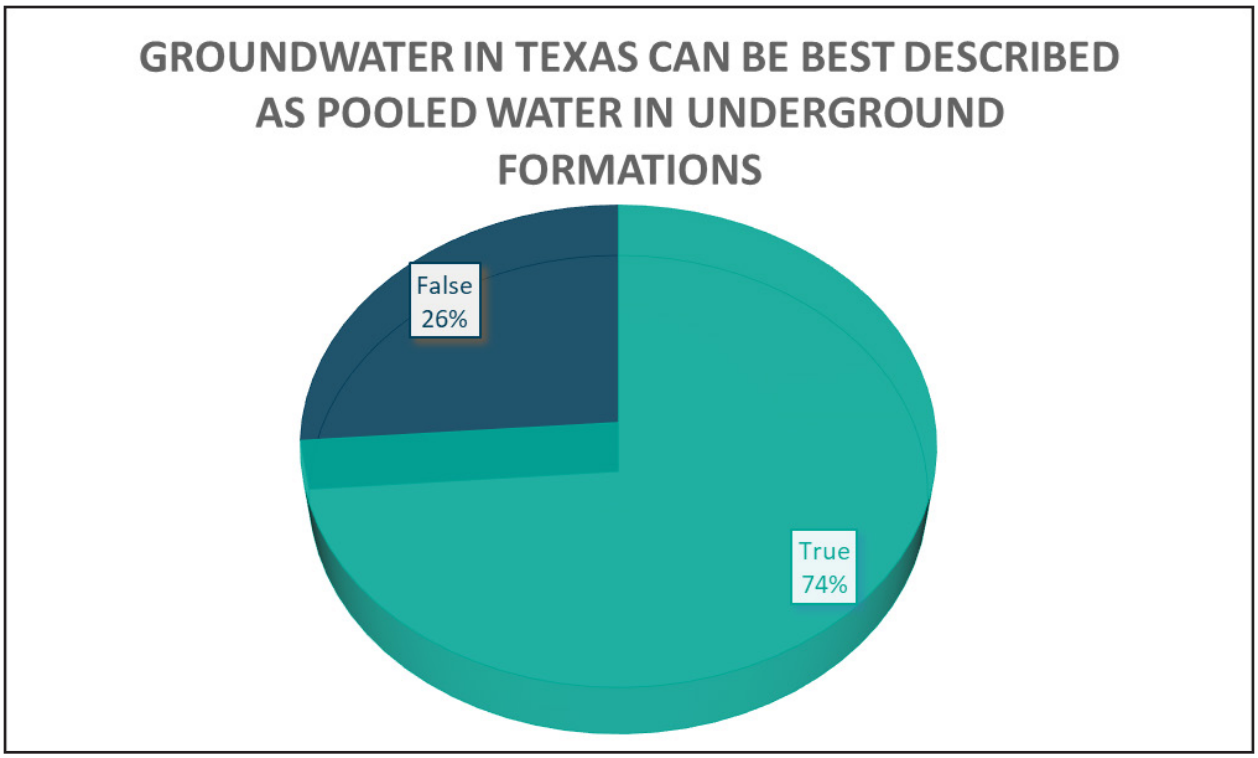


Figure 8B. Location and Nature of Groundwater Results for Mailed Survey

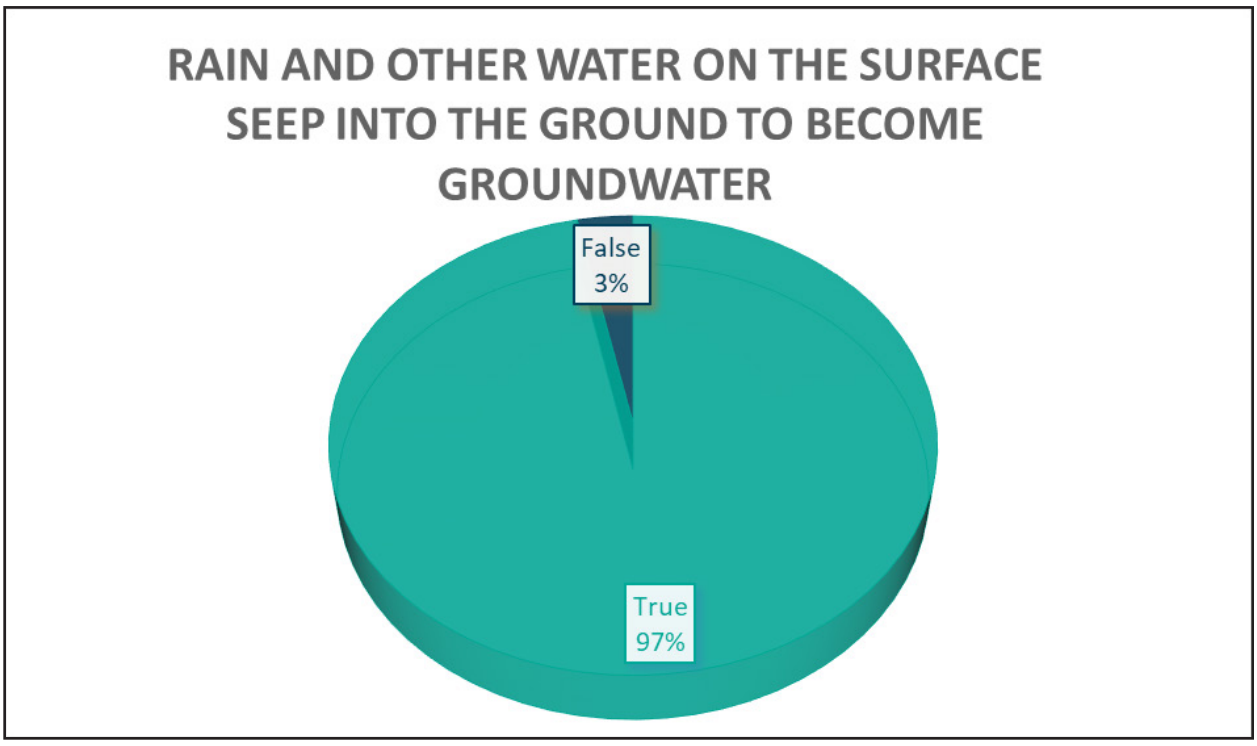


Figure 9A. Source of Groundwater Results for Online Survey

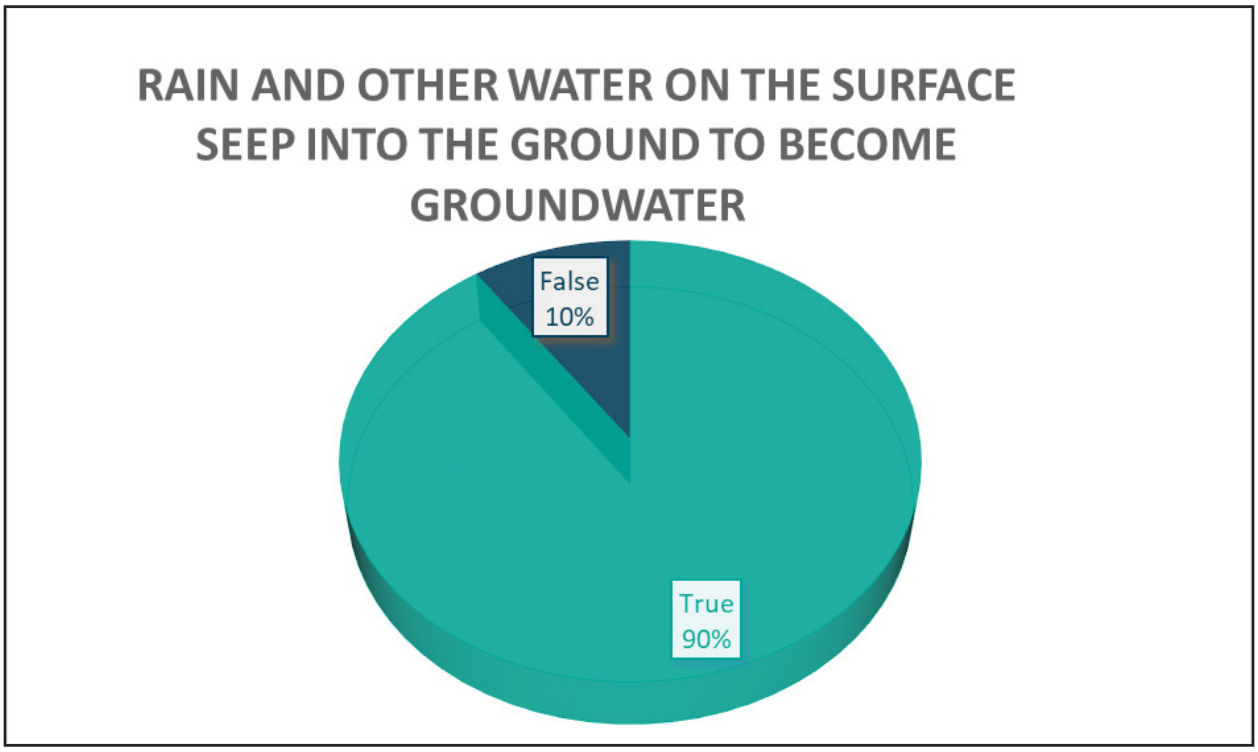


Figure 9B. Source of Groundwater Results for Mailed Survey

6. PERCEPTIONS OF GROUNDWATER AVAILABILITY

6.1 In general, groundwater is plentiful and will always be available for human use.

The objective of questions 10A and 10B is to gauge survey participants' perception of, and beliefs about, the general availability of groundwater (Figures 10A and Figure 10B). An additional response option of 'Don't Know' was provided in the mailed survey.[4] Figures 10A and 10B show that a higher percentage of respondents are not optimistic about groundwater availability, despite not being able or willing to name the aquifer that provides the groundwater, or knowing about its health.

Question 11 is a follow-up question to Question 10. Figures 11A and 11B show the responses. The question asks about respondents' perceptions and beliefs regarding current and future availability of groundwater at the county and state level. 62% (186) of online respondents to this question agree that groundwater is enough to meet current needs at the county level against 38% (114) who disagree with this statement. However, only 24.75% (73) of respondents feel that current needs are being met at the state level, while 75.25% (222) do not. 17.79% (50) agree that groundwater will be available at the county level for the next 25 years compared to 82.21% (231) who disagree with this statement. Respondents feel more optimistic about groundwater being available to meet current needs at the state level than being available to meet the needs of the state for the next 25 years. 5.05% (15) of respondents feel that there will be groundwater availability at the state level for the next 25 years compared to 94.95% (282) who do not feel so.

There are two observations of note. First, respondents are more sanguine about the availability of groundwater to meet current and future needs at the county level than they are about its availability at the state level. Second, there were fewer online respondents to this question compared to those who responded to the demographic and general groundwater knowledge questions. That is, fewer people responded to the question about groundwater availability to meet future needs of the county for the next 25 years. This suggests some reluctance of respondents to project into the future, and the uncertainty they feel over this issue. Those who did were pessimistic about the outcome. This may be due to respondents seeing the intense pressures being placed on groundwater close to where they live and the implications of this for the future. Focus groups conducted statewide in a future research study would provide some insight for this pessimism.

Figure 11B shows that when this same question was posed to those who received the mail survey and were given the option of a 'Don't Know' response, many expressed this uncertainty. Further, almost all the mail survey takers answered this question.

[4] This was an inadvertent error, but the results are included since they are informative in their own right.

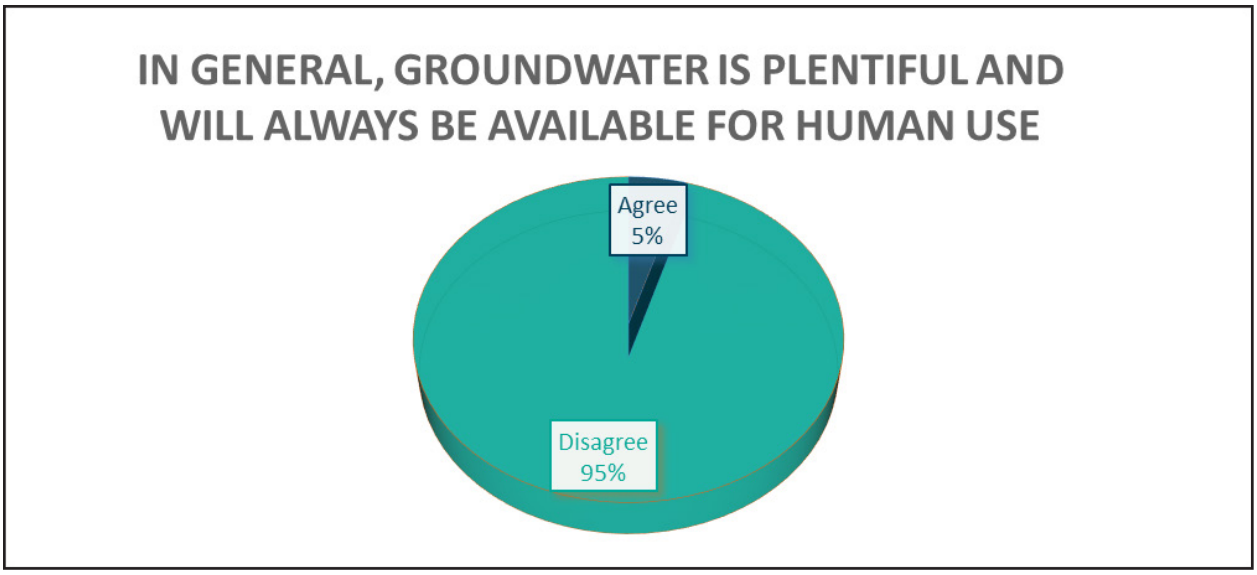


Figure 10A. Results of Perception of Groundwater Availability for Online Survey

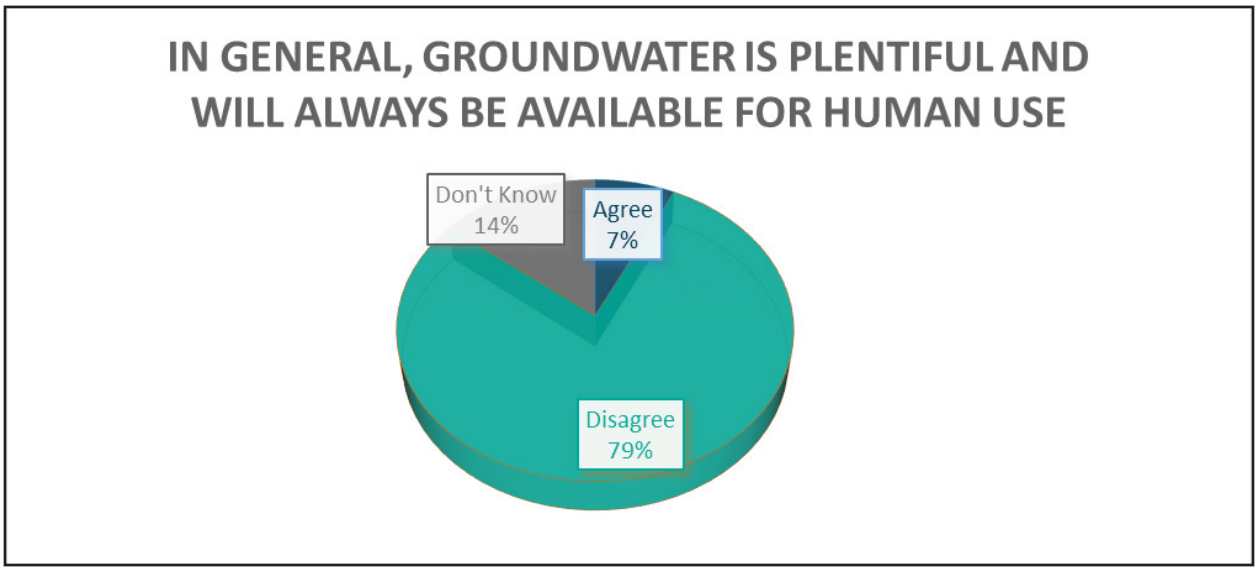
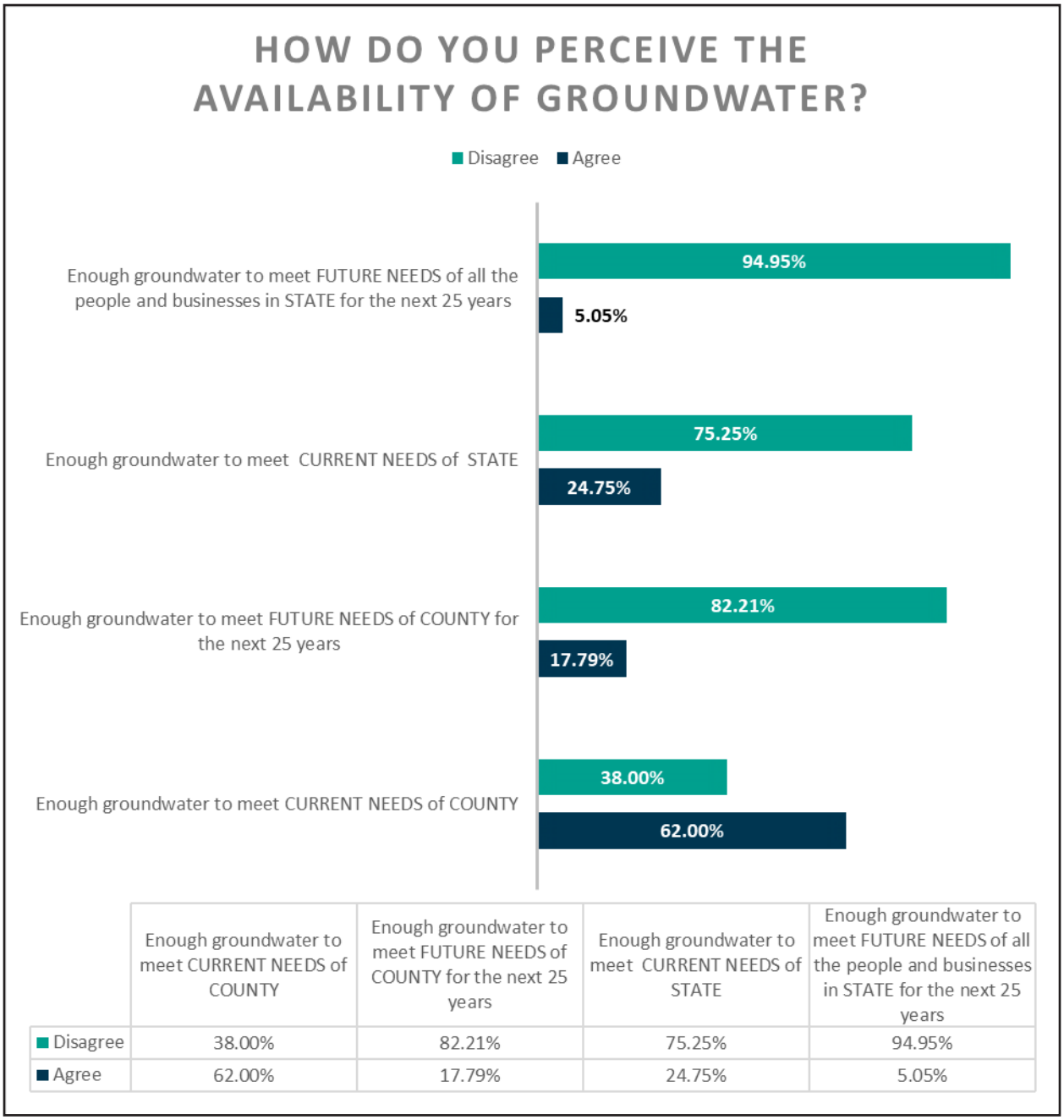
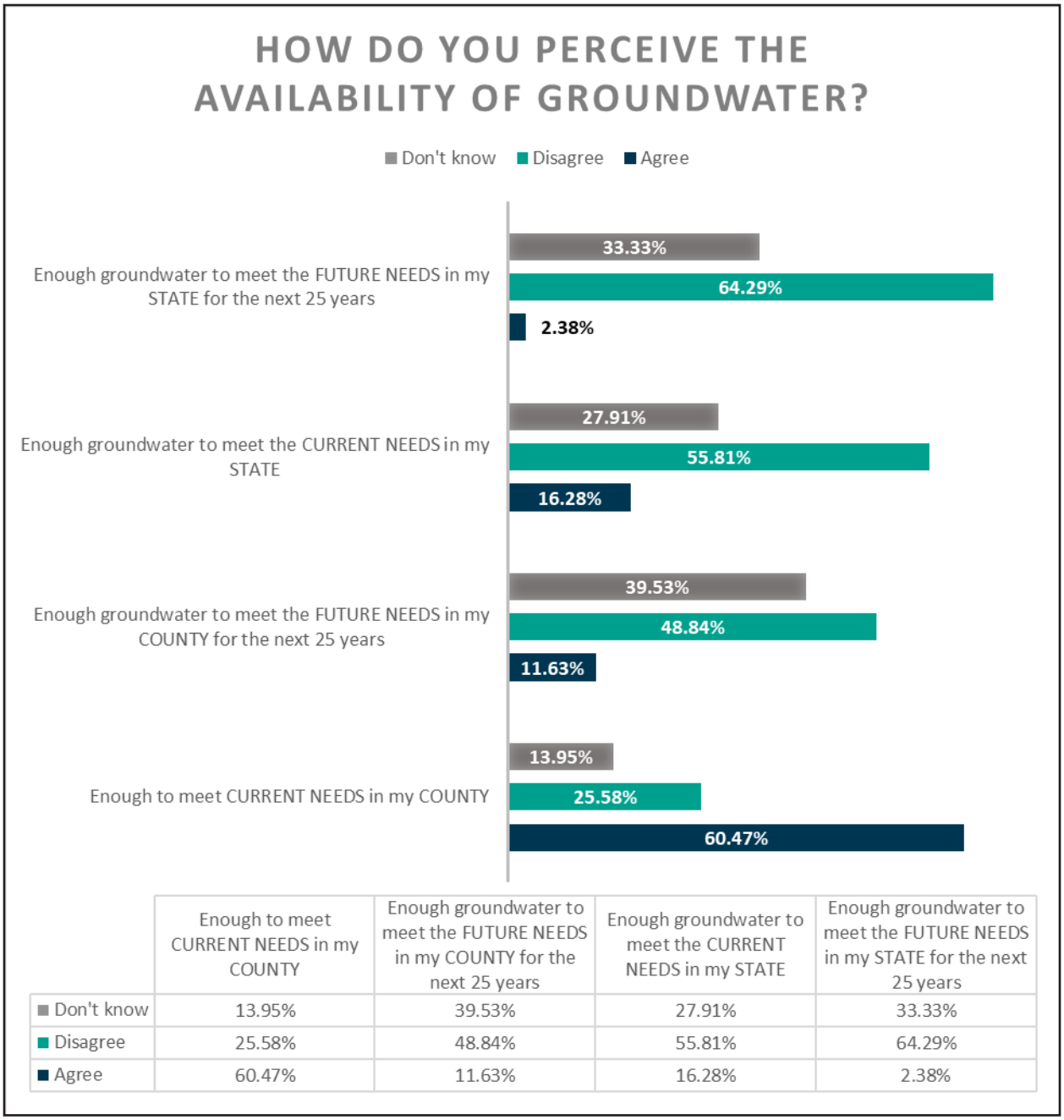


Figure 10B. Results of Perception of Groundwater Availability for Mailed Survey



	Enough groundwater to meet CURRENT NEEDS of COUNTY	Enough groundwater to meet FUTURE NEEDS of COUNTY for the next 25 years	Enough groundwater to meet CURRENT NEEDS of STATE	Enough groundwater to meet FUTURE NEEDS of all the people and businesses in STATE for the next 25 years
Disagree	38.00%	82.21%	75.25%	94.95%
Agree	62.00%	17.79%	24.75%	5.05%

Figure 11A. Results of Perceptions Regarding Current and Future Availability of Groundwater at the County and State Level for Online Survey



	Enough to meet CURRENT NEEDS in my COUNTY	Enough groundwater to meet the FUTURE NEEDS in my COUNTY for the next 25 years	Enough groundwater to meet the CURRENT NEEDS in my STATE	Enough groundwater to meet the FUTURE NEEDS in my STATE for the next 25 years
Don't know	13.95%	39.53%	27.91%	33.33%
Disagree	25.58%	48.84%	55.81%	64.29%
Agree	60.47%	11.63%	16.28%	2.38%

Figure 11B. Results of Perceptions Regarding Current and Future Availability of Groundwater at the County and State Level for Mailed Survey

7. PERCEPTIONS OF GROUNDWATER QUALITY

7.1 Impact of land use and practices - Please rate each of the following land uses and practices on their potential to have a negative or detrimental impact on groundwater quality in your area, with 0 having no negative or detrimental impact and 5 having a high negative or detrimental impact.

This question asks respondents to rate a list of 5 land uses and practices on a scale ranging from 0 to 5 (0 = no negative or detrimental impact, 5 = high negative or detrimental impact). Almost all (online and mail survey) respondents answered this question (335 and 41 respondents respectively) (Figure 12). The highest negative impact mean score (4.30) was attributed to Industrial areas and cities with a standard deviation of 1.02. Parks and recreational lands had the lowest negative impact mean score (1.63), and standard deviation of 1.29. Following these two were Septic tanks and waste (3.50) and Lawns, gardens, and general landscaping (3.17), with standard deviations of 1.39 and 1.37 respectively. Ranch lands and farm lands appeared relatively lowly rated on the detrimental scale; it's standard deviation for data representing online respondents was the highest of land uses at 1.50. Values have been generated for these data to represent position on a scale and should not be interpreted to reflect the strength of personal feelings about these uses/practices on groundwater; nevertheless, the data reveal that some disagreement exists among respondents about the overall impact of each of the land uses.

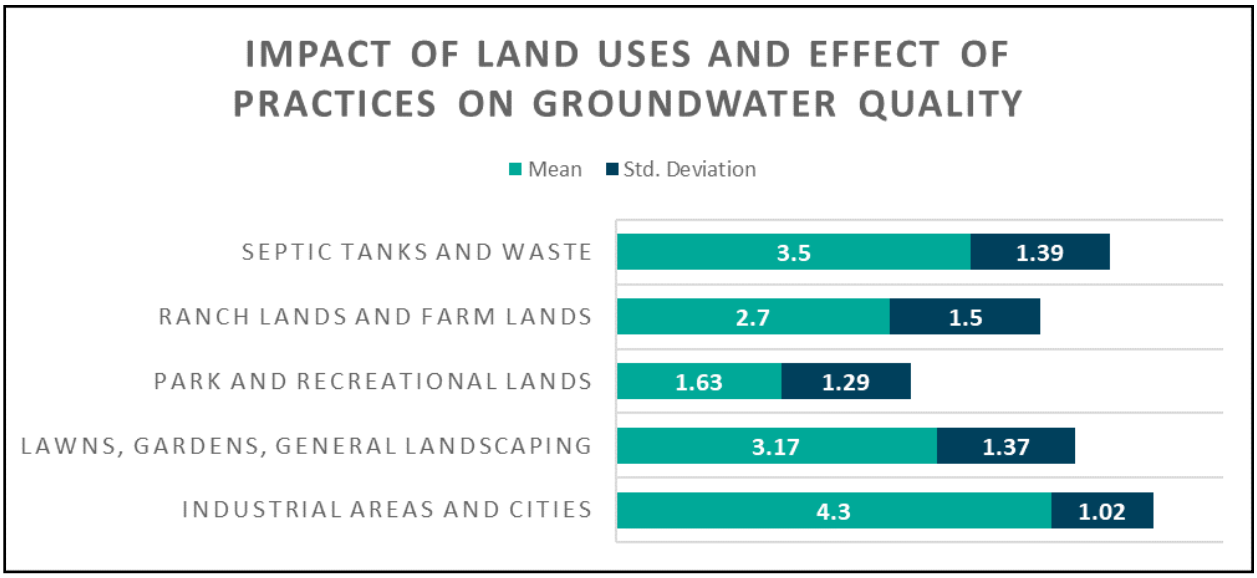


Figure 12A. Online Survey Results of Rating the Impact of Land Uses and Practices on Groundwater Quality

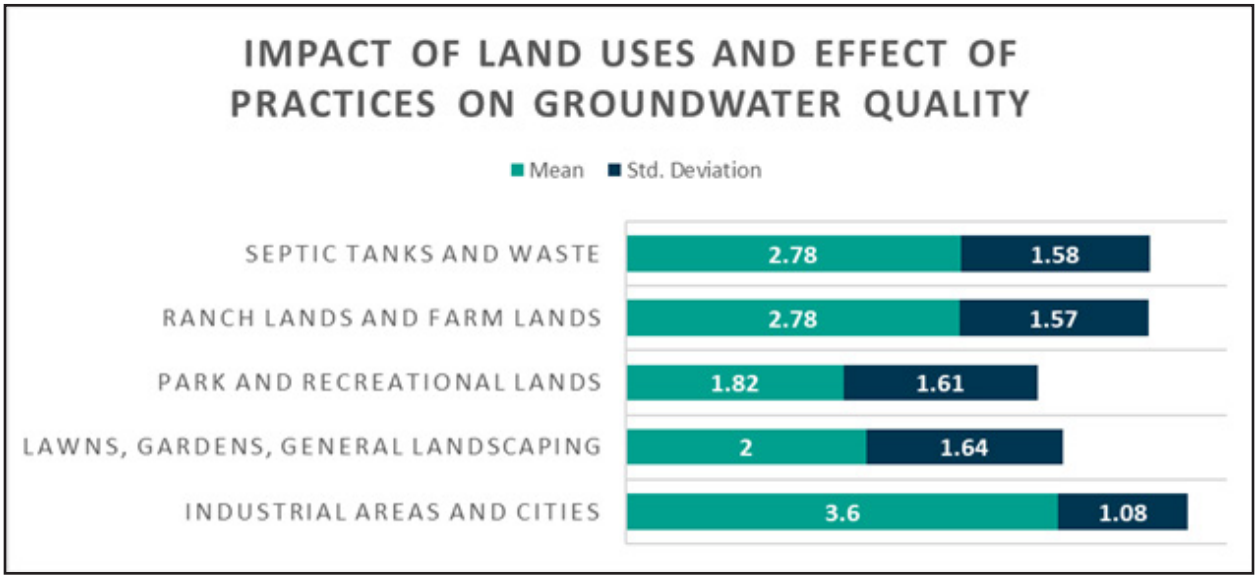


Figure 12B. Mailed Survey Results of Rating the Impact of Land Uses and Practices on Groundwater Quality

7.2 Please rate each of the following pollutants on their potential to have a negative or detrimental impact on groundwater quality in your area, with 0 having no negative or detrimental impact and 5 having a high negative or detrimental impact.

Online respondents attributed the highest negative or detrimental impact mean score to Gasoline or oil (4.15), followed by Herbicides (Weed control). Figure 13A shows that standard deviation was relatively low for the Herbicides category. Respondents gave the lowest impact mean score to Trash or Garbage, although this category had the highest standard deviation. The mean scores for Industrial and Household Chemicals and Fertilizers were almost equally rated with mean scores of 3.93 and 3.94 respectively. Insecticides were not rated all that highly but had the second highest standard deviation. It should be noted that neither Ranchlands and Farmlands, nor Insecticides are viewed as having a high negative or detrimental impact on groundwater, relatively speaking, when viewing mean scores. Figure 13B shows that Central Texas residents had only the lowest ranked Trash or Garbage ranking in common with online respondents. There were 331 online and 41 mailed survey respondents to this question.

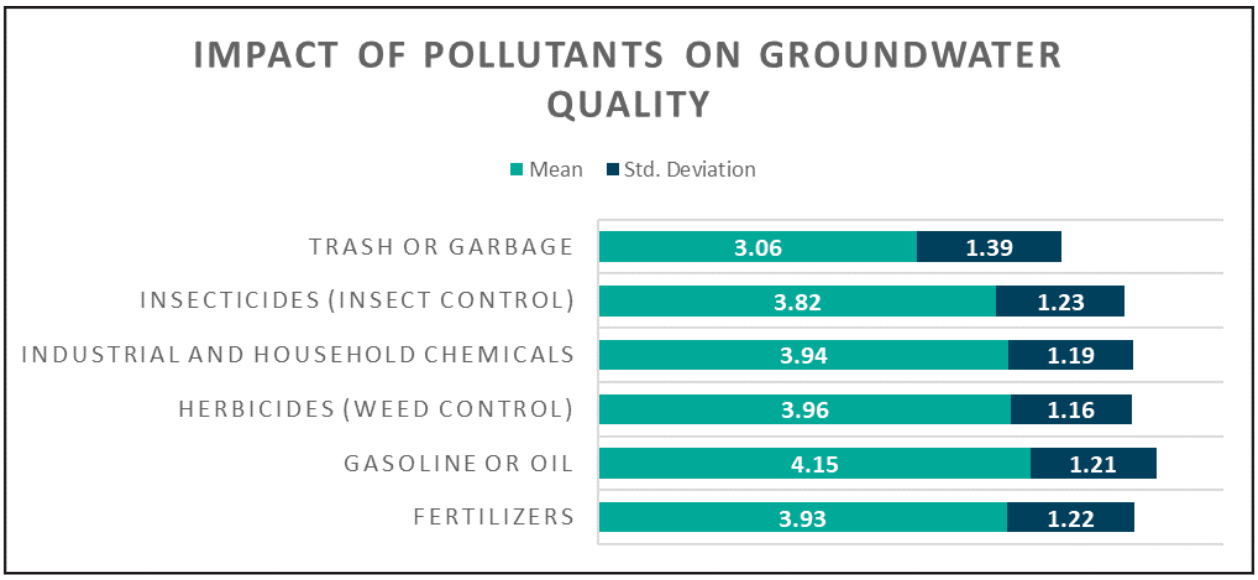


Figure 13A. Online Survey Results of Rating the Impact of Pollutants on Groundwater Quality

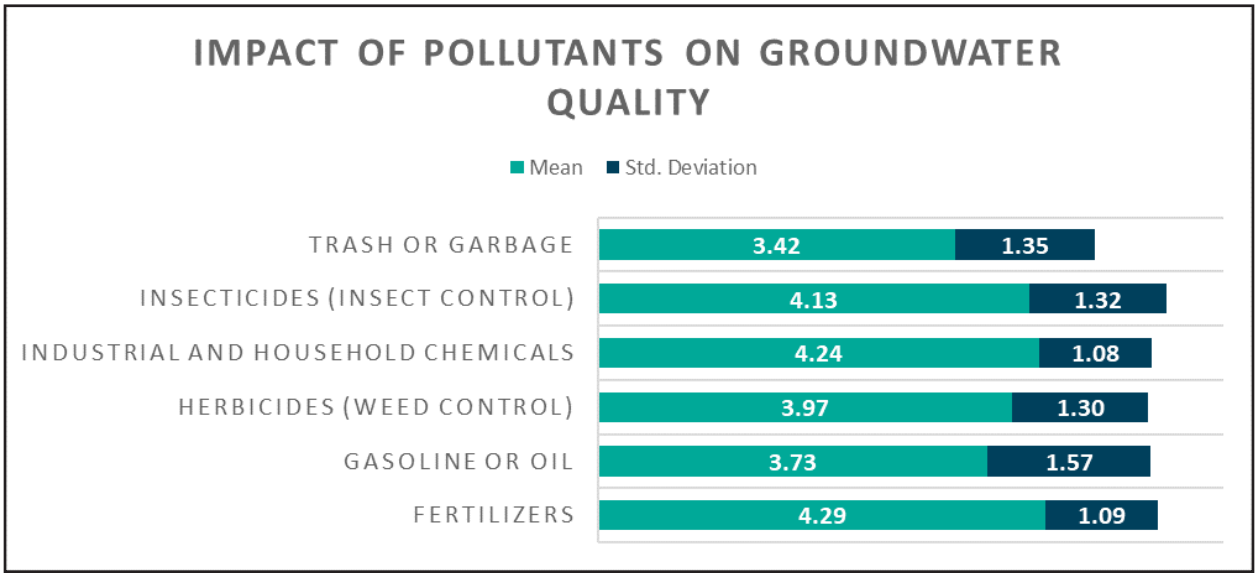


Figure 13B. Mailed Survey Results of Rating the Impact of Pollutants on Groundwater Quality

8. SOURCE(S) OF DRINKING WATER

8.1 Please indicate your main source(s) of drinking water. Check all that apply.

Respondents could check all responses that applied (Figure 14A and 14B). Comments were solicited for this question and are listed below. There were 320 online respondents and 41 mailed survey respondents who chose to answer this question. Most online respondents identified a public supply of water as their main source of drinking water, either from groundwater (38.13%) or surface water (48.75%). Although private wells are often a source of publicity and even conflict when groundwater supplies are threatened, they are identified by only 19.06% of respondents as a main source of drinking water, behind bottled water (23.44%). Harvested rainwater is by far the least relied upon (5.31%) as a main source of drinking water. One comment indicated that the respondent knew that the source was a public supply, but not whether it was groundwater or surface water. Of course, since all or any combination of responses could be chosen, answers to this question show that harvested rainfall and private well were not the primary sources of drinking water for most online respondents. The comments that follow the figures show that some respondents know their public supply depends on both groundwater and surface water. Additional comments show respondents are finding drinking water from sources other than those presented in this question.

Mailed survey respondents saw their main sources of drinking water from private wells or bottled water (48.83% and 37.21% respectively). There was one respondent in each of the 'I don't know' and 'Other' categories.

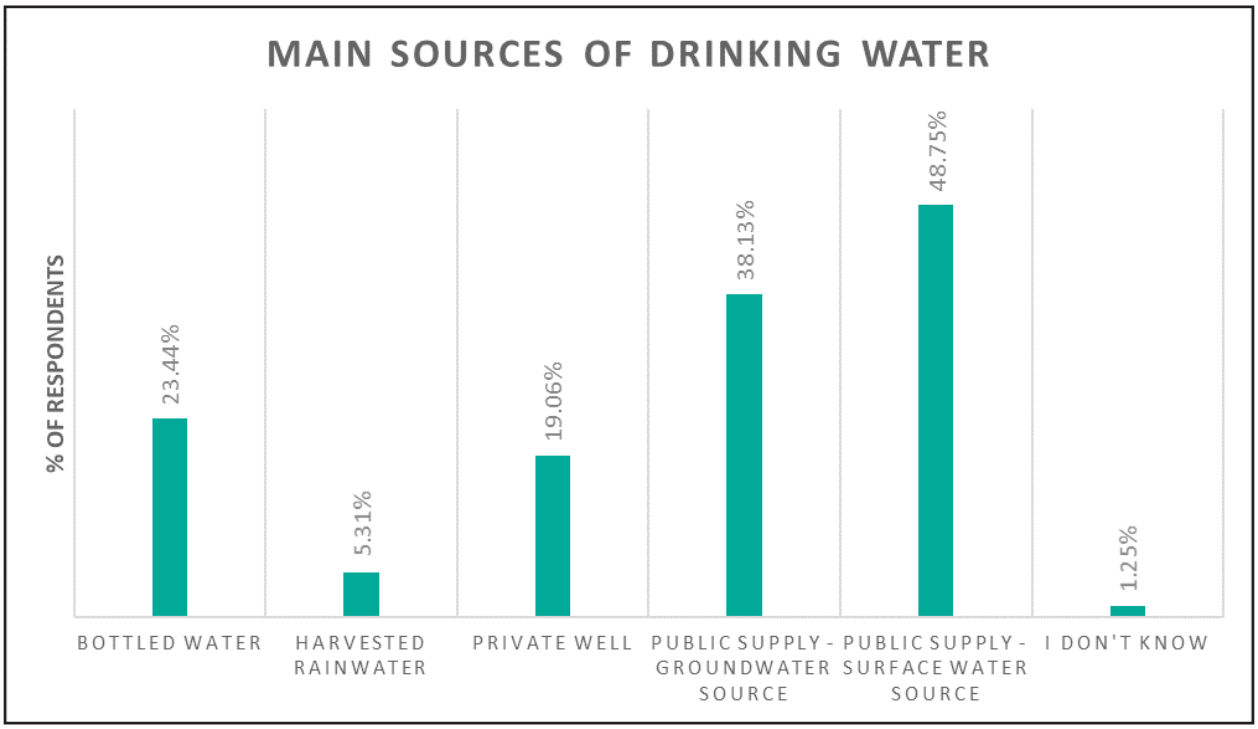


Figure 14A. Results of Main Sources of Drinking Water for Online Survey

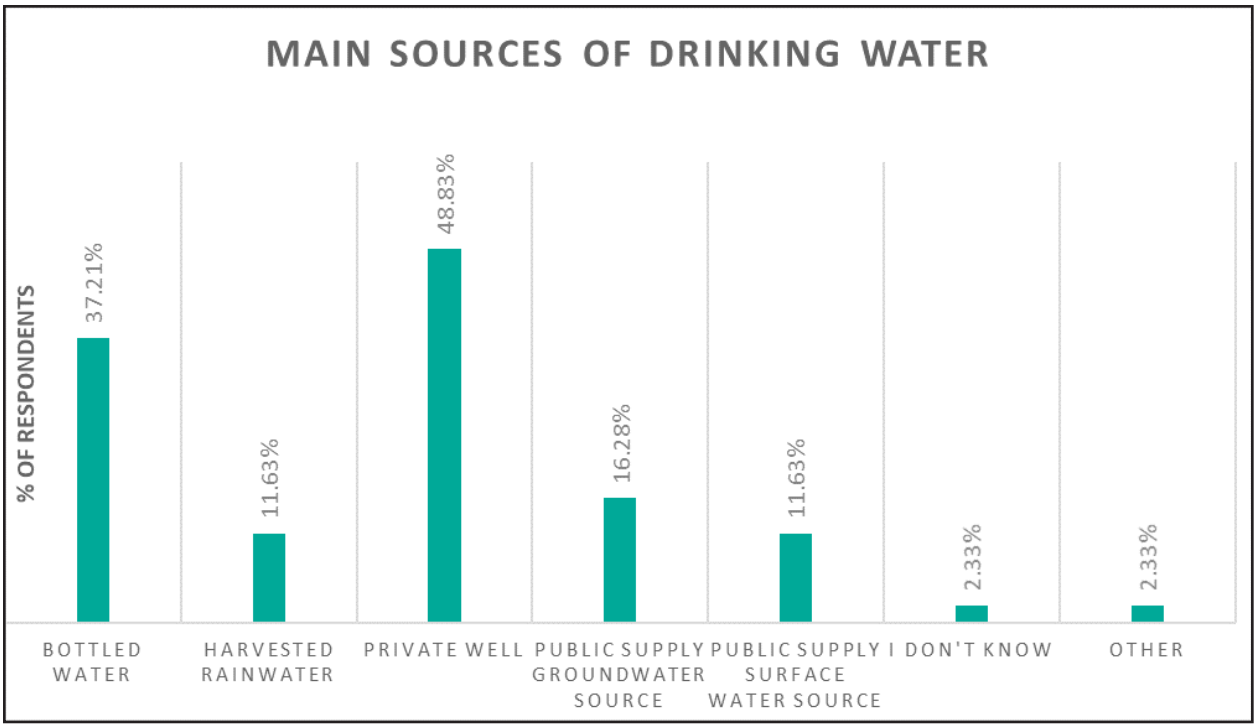


Figure 14B. Results of Main Sources of Drinking Water for Mailed Survey

Responses to 'Other'
Bulk bottled and delivered groundwater from local company Cielo
Public Water Supply - Blend of Groundwater source 30% and Surface Water source 70%
Purchase from a private RO plant
Purified tap water
Filtered public supply
I filter the public water supply coming into my house.
Private Spring fed system
Reverse osmosis of city water
Public, but I'm not sure if it is ground or surface water sourced
Spring Water
Spring water in glass container
Mixture of groundwater and river water from Canyon Lake
Filtered public water purchased (e.g. Glacier water dispenser)
Desalination of brackish water
Reverse Osmosis Filter under kitchen sink to filter public water
Public Supply with both groundwater and surface water sources

9. GROUNDWATER PRIORITY OF USE

9.1 During times of groundwater scarcity due to increased demand or decreased supply, there may not be adequate groundwater to provide for all groundwater uses. Listed below are SEVEN OPPORTUNITIES TO PLAN FOR PROVIDING WATER IN THE FUTURE IN CASE GROUNDWATER SOURCES ARE LIMITED. Please rank the uses from 1 (highest priority) to 7 (lowest priority) in terms of what you believe are acceptable opportunities that should be planned for.

There were seven answer choices for respondents on this question. Respondents were requested to choose from opportunities for providing water in the future in case groundwater sources became limited (Figures 15A and 15B). They were to assign a 1 for highest priority options to a 7 for lowest priority. Between 310 and 319 online respondents chose to answer different parts of this question. It is not surprising that fewer respondents chose to answer this question because of the number of options given and each question required some reflection. Between 36-38 respondents chose to answer this question on the mailed survey.

Building underground storage space for water supply was ranked lowest by 11.9% of 311 respondents. It was ranked highest by 16.4% of respondents. 27.01% of those who chose this response ranked this option as #6 (second lowest importance). Although this option has become a choice by municipalities such as San Antonio, the public seems to either favor it or not consider it favorable, with only modest percentages of respondents favoring this option in the middle ranges.

312 people responded to the option of Buying or transporting water from another location to augment current groundwater supplies. This option, too, has received quite a bit of publicity and is particularly controversial. 42.6% of respondents assigned this option the lowest priority; 26.2% and 11.5% gave it priorities of #6 and #5, respectively. It was favored by only 3.1% as the highest priority. Priorities were in the single digits for other priority scores.

Limiting the growth of cities to a level that is supported by a sustainable supply of groundwater is a question that seems to polarize respondents. 313 respondents chose to provide their ranking of this option. This option was ranked highest by 25.5% of respondents, 24.28% ranked this option lowest. There was almost an equal number of this option ranked as #5 (15.9%) and #6 (15.6%).

Respondents seem to strongly favor Requiring households to take steps to conserve the use of groundwater. Almost 88% of those responding to this option ranked it #1 - #4 in priority. This fact emphasizes the importance of education, communication, and the participation of water users at the local level in groundwater conservation, preservation, and protection of this natural resource. An important consideration is likely to be the voluntary or involuntary nature of household conservation practices.

There did not appear to be a polarization of responses when a market approach was considered. Restructuring rates on water usage was ranked above 15% as priority #2 - #5, with #2 receiving the highest priority (20.77%). A market approach received the lower rankings (#6 and #7) in the single digits. This suggests that water users may not have an aversion to economic disincentives when it is evident that groundwater supplies are limited or being threatened. However, one comment at the end of the survey expressed dissatisfaction that revenues were generated from this approach, but rates were not lowered when the water crisis was over.

Reuse of treated wastewater as a means of preserving groundwater is less often presented as an option to water users. Respondents give higher priority to this approach when considering its use on lawns and landscapes

than within the home. The data suggests that the science and safety of treated wastewater is probably poorly understood by the public, since its use is already widespread in water conservation, is safeguarded by regulation and an important part of water policy.

Central Texas residents are also less than favorably disposed toward Building underground storage space as a future source of water supply. The option of Buying or transporting water from another location seems to elicit an almost equally unfavorable response from residents receiving the mailed survey. An almost equal percentage (18.92%) of respondents ranked Limiting the growth of cities as Priority 1 and Priority 7 (16.22%). However, 37.83% ranked this option as Priority 2. Figure 15B shows that the most frequently occurring response from central Texas residents is to place responsibility on households to conserve the use of groundwater. Restructuring rates, a market-oriented approach, also received lower rankings from central Texas residents, as was the case with online residents. This may be because groundwater rates are felt locally, and the data reflects the sentiments and sensitivity of residents to this fact. Reuse of treated wastewater within the home is not as highly a ranked choice by central Texas residents as is its use outside of the home.

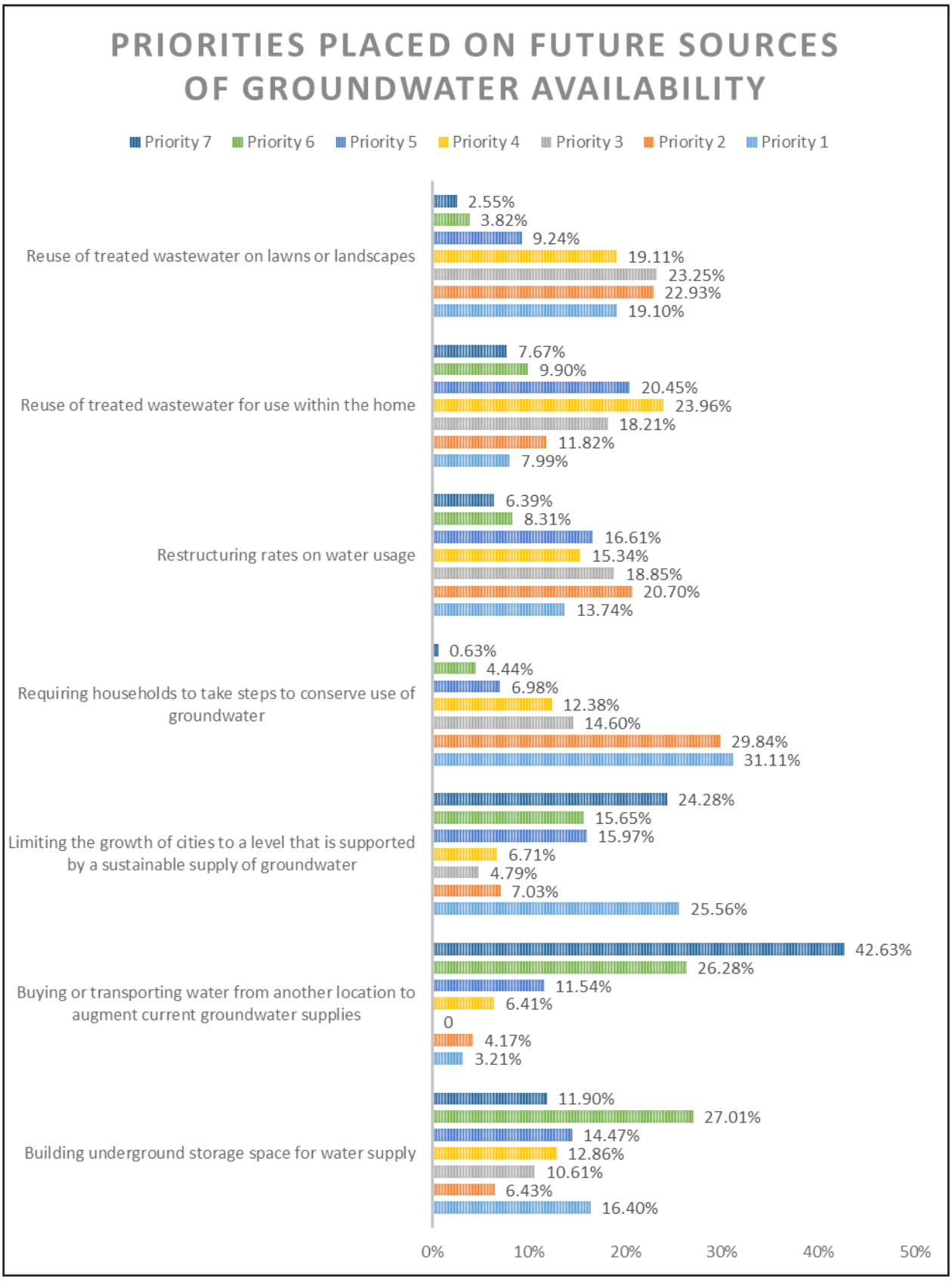


Figure 15A. Online Survey Results of Ranked Opportunities for Future Sources of Groundwater Availability

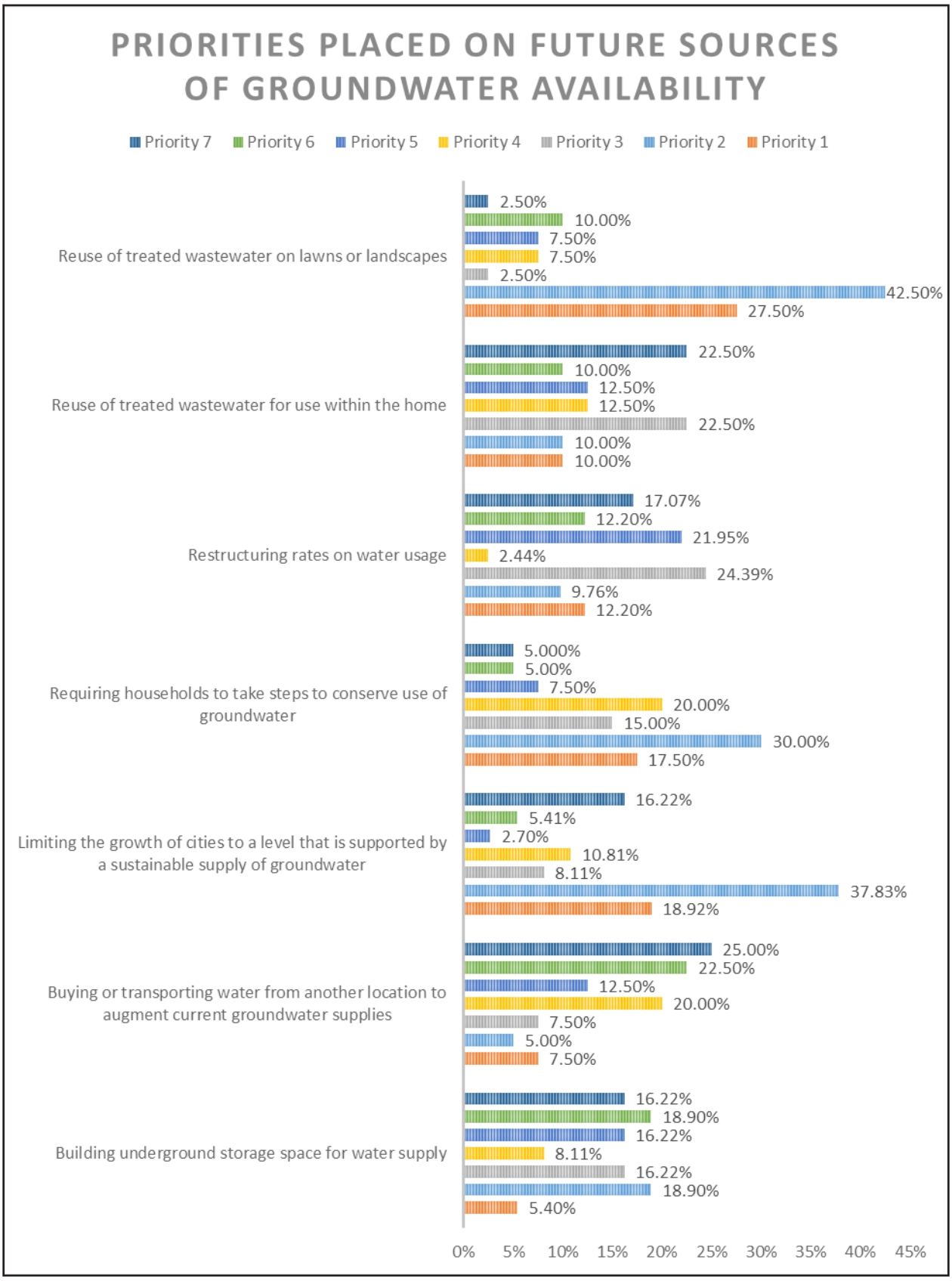


Figure 15B. Mailed Survey Results of Ranked Opportunities for Future Sources of Groundwater Availability

9.2 Listed below are SEVEN USES FOR WHICH GROUNDWATER MIGHT BE ALLOCATED DURING TIMES OF INCREASED DEMAND OR DECREASED SUPPLY. Please rank the uses from 1 (highest priority) to 7 (lowest priority) in terms of appropriate or acceptable allocations.

Groundwater allocation to different uses during times when the resource is under stress is important to communities and policy makers alike. Figures 16A and 16B show that allocating groundwater to households for various uses and the natural environment were assigned the highest priority ranking. In Figure 16A, household uses were assigned the highest priority by 45.45% of the 319 online responses to this question, compared to 61.90% of those who received the mailed survey. Allocating groundwater to support fish and wildlife habitat received the highest priority by 35.22% of 318 online responses (30.95% mailed survey). Almost 96% of respondents chose household uses as priority #1 - #4 (95.22% mailed survey). Close to 95% of online respondents chose allocating groundwater to support the natural environment as priority #1 - #4 (83.33% mailed survey). Allocating groundwater to agricultural irrigation received almost equal responses for priorities #2 (25.71%), #3 (23.51%), and #4 (27.90%). 13.48% ranked agriculture as Priority 1. The data table provided in Figure 16B gives greater visibility to several priorities assigned by no respondents.

Allocating groundwater for household uses and the natural environment are perceived to be mutually exclusive. The data suggest that household uses are considered important, but there is concern about fish and wildlife habitat as well as the natural environment. This fact should be considered when formulating and implementing policy at the state level.

Central Texas residents place a high priority on household uses. Respondents also indicated priority to allocating groundwater for natural resource management (instream and wetland management) with 94.34% of 318 responses rating between priorities #1 and #4. Agricultural irrigation was ranked as priority #2 (30.95%), #3 (19.04%) and #4 (16.66%), but this use was ranked Priority 1 by 19.04% of these same residents. Municipal and private landscaping, and recreation received lower priority rankings.

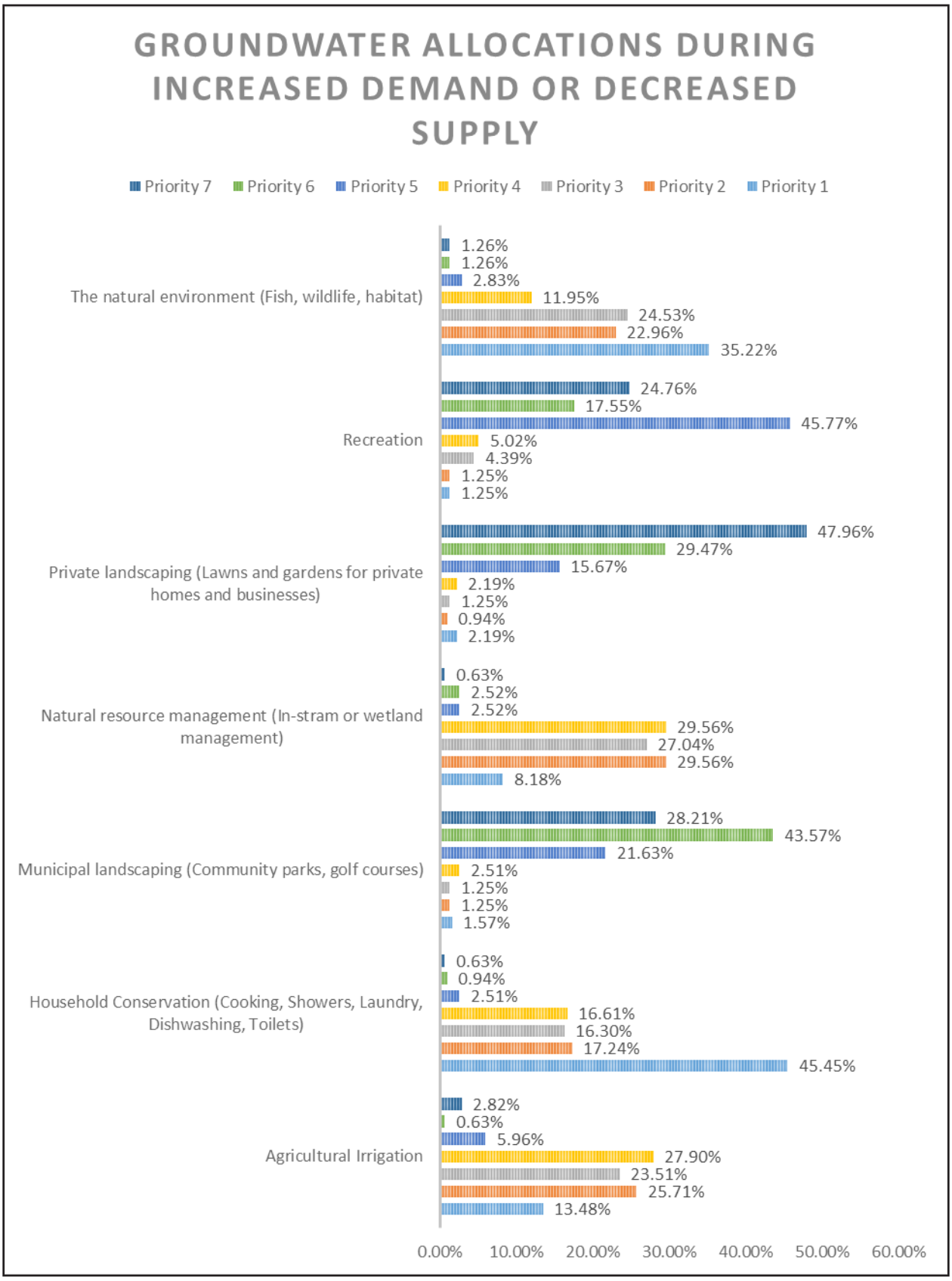
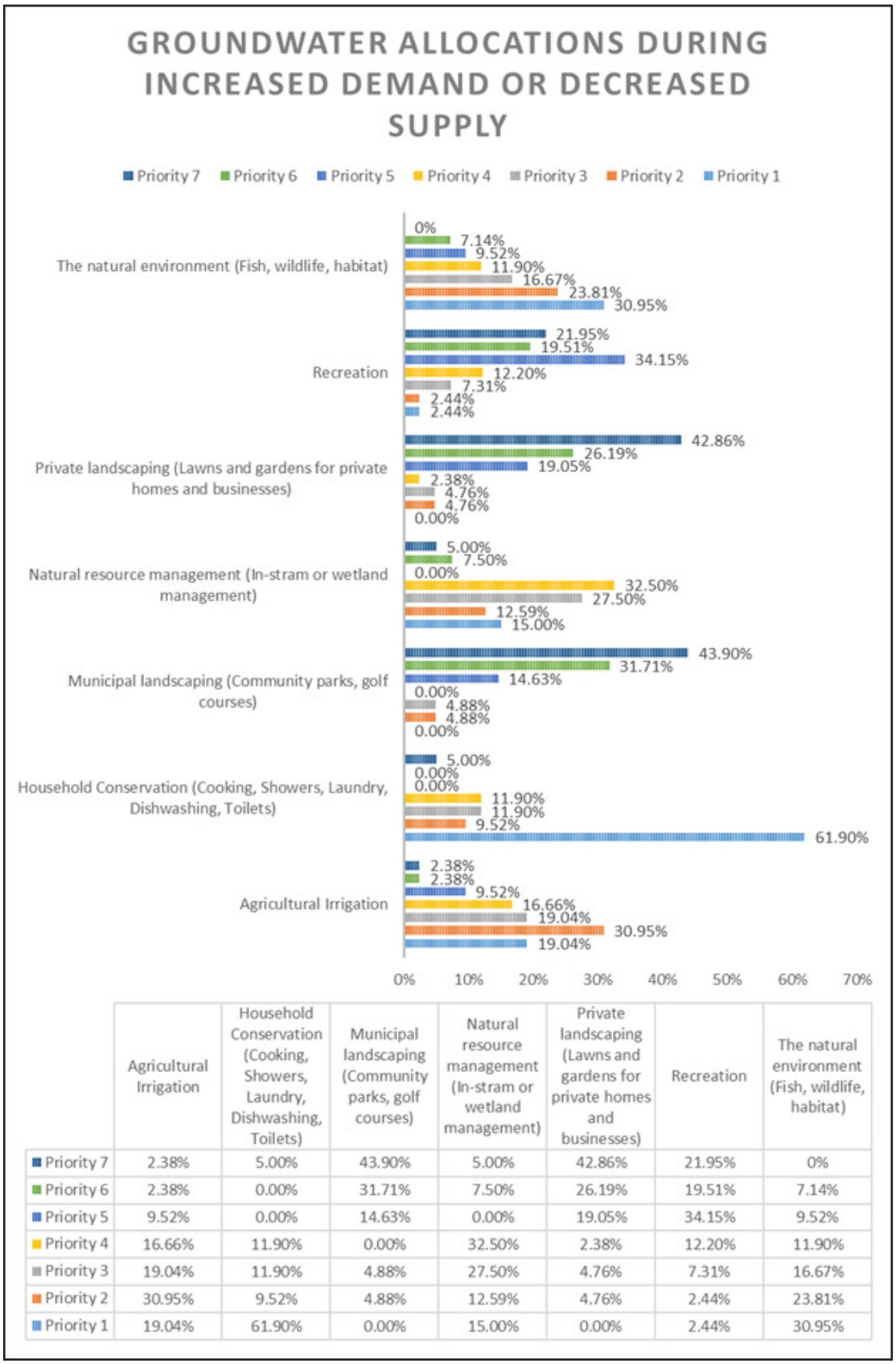


Figure 16A. Online Survey Results for Ranking Seven Uses for Which Groundwater Might Be Allocated During Increased Demand or Decreased Supply



	Agricultural Irrigation	Household Conservation (Cooking, Showers, Laundry, Dishwashing, Toilets)	Municipal landscaping (Community parks, golf courses)	Natural resource management (In-stram or wetland management)	Private landscaping (Lawns and gardens for private homes and businesses)	Recreation	The natural environment (Fish, wildlife, habitat)
Priority 7	2.38%	5.00%	43.90%	5.00%	42.86%	21.95%	0%
Priority 6	2.38%	0.00%	31.71%	7.50%	26.19%	19.51%	7.14%
Priority 5	9.52%	0.00%	14.63%	0.00%	19.05%	34.15%	9.52%
Priority 4	16.66%	11.90%	0.00%	32.50%	2.38%	12.20%	11.90%
Priority 3	19.04%	11.90%	4.88%	27.50%	4.76%	7.31%	16.67%
Priority 2	30.95%	9.52%	4.88%	12.59%	4.76%	2.44%	23.81%
Priority 1	19.04%	61.90%	0.00%	15.00%	0.00%	2.44%	30.95%

Figure 16B. Mailed Survey Results for Ranking Seven Uses for Which Groundwater Might Be Allocated During Increased Demand or Decreased Supply

10. KNOWLEDGE OF AND INTERACTION WITH GROUNDWATER MANAGEMENT

10.1 Groundwater Conservation Districts are locally governed districts responsible for developing and implementing plans for the effective management of groundwater resources. Are you aware of the existence of these districts?

Groundwater conservation districts are the primary means of implementing groundwater policy at the local level. They provide services related to private wells, educate the public on groundwater issues and communicate with the public during times when there is lack of groundwater availability. A majority of the 319 online respondents and 41 mail survey respondents were aware of the existence of these districts (Figures 17A and 17B).

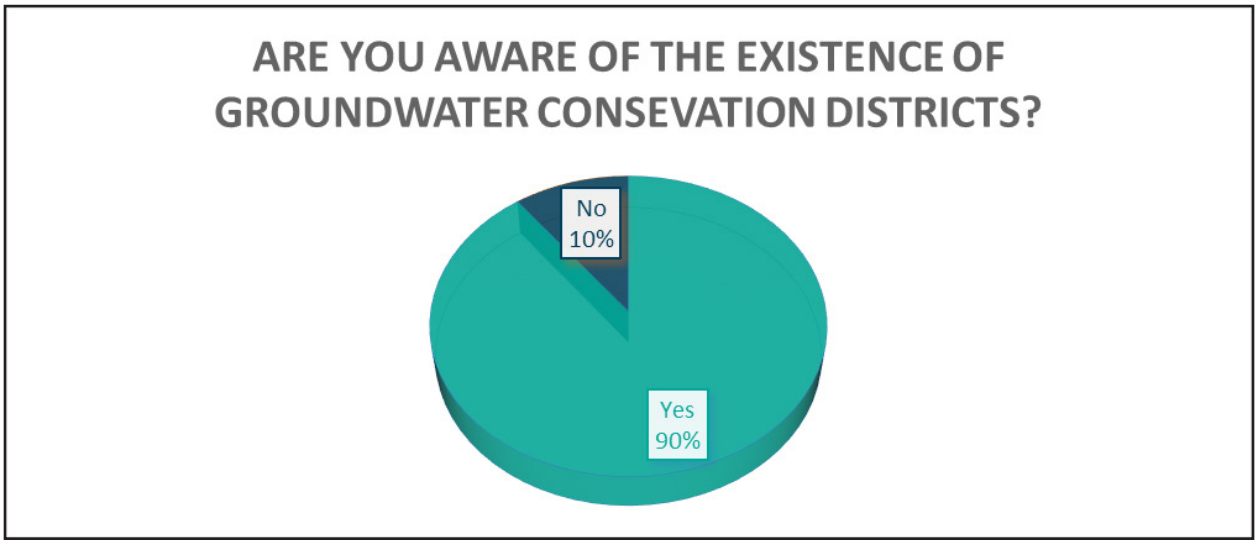


Figure 17A. Results of Knowledge of the Existence of Groundwater Conservation Districts for Online Survey

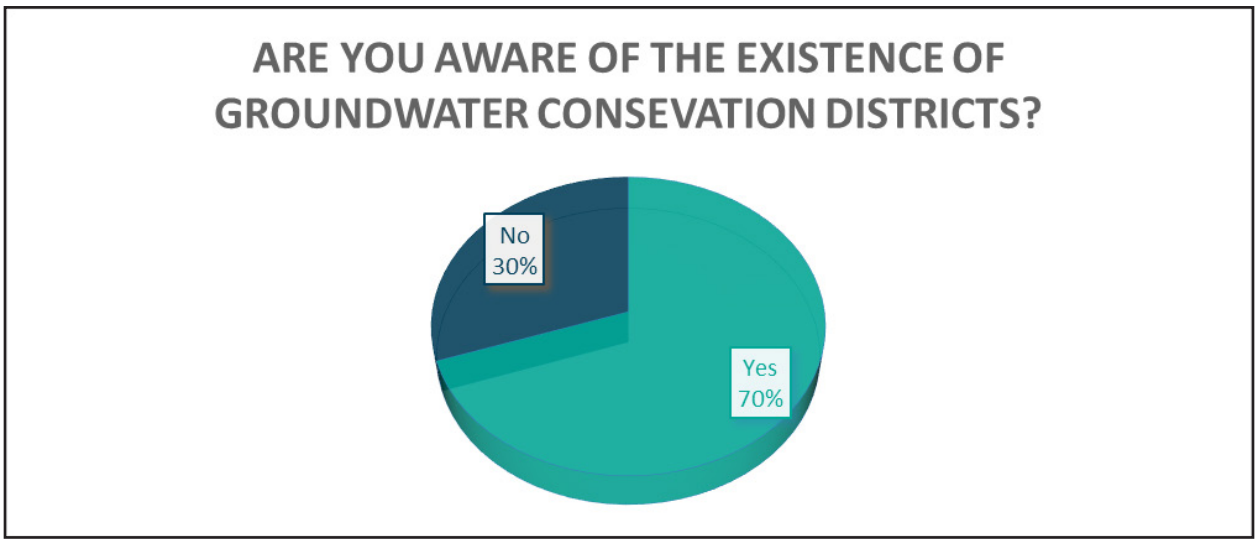


Figure 17B. Results of Knowledge of the Existence of Groundwater Conservation Districts for Mailed Survey

11. DISCUSSION OF FINDINGS

Groundwater is generally understood as being water located beneath the surface of the earth and recharged from above-ground sources of water. This knowledge did not seem to translate into specific knowledge about the aquifer source of their groundwater, since in an open-ended comment section, few respondents could or chose to name the aquifer supplying their groundwater.

The motivation for this study lies in the increased demand for groundwater, and threats to its supply. It was useful to determine respondents' perceptions of its availability. Online respondents to this question were not optimistic about its general availability. Different responses were provided by mail survey respondents because slightly different response options were posed to them. Mail survey respondents were given an opportunity to answer this same question but chose to express uncertainty about general availability, because they were given this option. Sentiments about general availability of groundwater may include an underlying uncertainty based on lay knowledge about a source of water which cannot be seen and can only be gauged by extreme weather conditions, academic knowledge, or professional and technical expertise.

When a question about current and future availability of groundwater on the county and state level was posed, the responses were more nuanced. A higher percentage of online respondents answering this question agreed that there would be enough groundwater to meet current needs at the county level than those who disagreed. This was true of mail respondents as well. Over the long term, both sets of respondents felt that groundwater would not meet future needs in 25 years either at the county or state level. However, a notable percentage of mail survey respondents chose 'Don't know' in addition to the 'Agree/Disagree' option, underscoring that a lack of knowledge may underlie uncertainty about the availability of groundwater over a time horizon.

Knowledge, perceptions and understanding of groundwater are understood within the context of factors which affect its quantity and quality. Survey respondents were asked to rate the Impact of land uses and the effect of practices on groundwater quality. Industrial areas and cities and Septic tanks and waste were rated by those surveyed online as having the two highest negative or detrimental impact on groundwater quality in the respondent's area. Industrial areas and cities were rated as having the highest negative or detrimental impact on groundwater quality in the respondent's area by those receiving the mailed version of the survey by mail as well, but Septic tanks and Ranch lands and farm lands were almost tied for second in the rating. However, they were viewed as having less detrimental impact than online respondents viewed Septic tanks. Gasoline and Oil and Industrial and Household Chemicals received high ratings as the pollutants deemed to have the most negative or detrimental impact on groundwater quality in the respondent's area followed closely by Fertilizers, Herbicides, and Insecticides. This was true of both sampled groups. Trash or Garbage was rated as having the least negative or detrimental impact on groundwater quality by both sampled groups as well.

The question on drinking water was asked so that the diversity of drinking water sources for the samples of respondents could be seen and understood in light of responses and concerns about groundwater gleaned from the data provided by the survey. Respondents could choose multiple sources. Data results show that Public supply – surface water source received the highest percentage of responses, followed by Public supply groundwater source from online respondents. Recall that online responses were received from all over the state of Texas; responses to the mailed survey were primarily central Texas residents. Those respondents who filled out the mailed form of the survey drew their main source of drinking water from a private well. A surprising result was the amount by which the percentage of mail survey respondents used bottled water as their main source of drinking water exceeded the percentage of online respondents. Drinking bottled water can be linked to concern over drinking water quality, as reported in other research (Clay et al., 2007). It is not clear whether this choice

made by mail survey respondents is a matter of personal preference, personal convenience, or related to their perception of the quantity or quality of groundwater.

During times of diminished groundwater availability, whether because of growing demand or threatened supply, it is useful to know how Texans would like to prioritize sources of groundwater, and allocations of its use. One question probed the priority which respondents placed on seven future sources of groundwater, and another probed seven uses for which they would like to see groundwater allocated in times of diminished availability. When asked about future sources of groundwater, online and mail survey-takers felt very differently. The data from the online survey showed that Building underground storage space for water supply and Buying or transporting water from another location to augment current groundwater supplies, was ranked lower by a higher percentage of respondents than Limiting city growth and Household conservation. Limiting the growth of cities polarized respondents, with an almost equal percentage of respondents giving this option a rank of Priority 1 and 7. The option of restructuring rates on water usage represented a market-based alternative, and the data show that respondents were not unwilling to use rates to ration groundwater usage to assure groundwater supply. Policymakers should be sensitive to the fact that citizens may expect that the restructuring of rates should reflect only the urgency of an immediate threat to groundwater availability. Central Texas residents, the primary respondents to the mailed survey, were not as amenable to ranking underground storage as Priority 1 as were their online counterparts. Buying or transporting groundwater from another location ranked low in priority. The mailed survey sample was more polarized over Limiting growth but still had more than double the percentage of respondents ranking this option as Priorities 1 and 2 than Priority 7. The percentage of central Texas residents answering this question placed high priority on the responsibility on households to conserve the use of groundwater, as did their online counterparts. A higher percentage of these respondents ranked Restructuring rates on groundwater usage as Priority 5-7 than did online respondents. Both samples viewed the use of treated wastewater inside the home more negatively than outside.

Conserving, preserving, and protecting groundwater provides for the natural environment and services for human health and well-being. Household uses was the option chosen by the highest percentage of survey takers, online and by mail. Private and municipal landscaping ranked last or almost last by both samples. Of note is the ranking given to the natural environment and natural resource management. In public discourse, allocating groundwater between the natural environment and providing for services for human health and well-being is often viewed as causing tension. The data show that respondents did see a distinction between groundwater allocation for the natural environment and for in-stream or wetland management. Both samples ranked groundwater allocation for the natural environment as among the first three priorities, although a lower percentage of online respondents ranked this allocation as the highest priority than did mail survey respondents. There is more of a uniformity of rankings for the natural environment between the sample groups than there is for natural resource management. This may be due to greater familiarity with natural environment needs than there is for natural resource management needs.

Since the responsibility for groundwater management is devolved to groundwater conservation districts, a question about knowledge of the existence of these districts is included in the survey. There was more familiarity with these districts, as shown by the response to this question, by online respondents compared to mail survey respondents. This result is somewhat surprising, but there may have been a greater number of online respondents with professional and technical knowledge or expertise. There were additional questions about respondents' knowledge and interaction with groundwater conservation districts which were not included in this report to accommodate the original mission and scope of the survey.

The results of the survey described in this report can be compared to findings from surveys carried out in related research and mentioned earlier in the Literature Review section. The Boellstorff et al. report surveyed

Texas residents about their perceptions and attitudes about surface and groundwater, and therefore some of the questions asked and the focus of these questions were quite different to those discussed in this report. However, some findings relevant to groundwater were similar in both reports. For example, participants in the Boellstorff survey appreciate the importance of groundwater. Bottled water is an important source of drinking water for many, although in both surveys, publicly supplied water is a primary source. Private wells constituted a source of drinking water for a larger percentage of Texas residents in this study. The Boellstorff study assessed Texas residents' perceptions of conditions that affected water quality in general, not specifically groundwater. Pesticides, fertilizers, petroleum products were identified as conditions contributing to the problem of water pollution. Industry and residential areas area also acknowledged in both studies to affect water quality. Respondents to the Boellstorff survey expressed concern about water shortages and restrictions in the future; this report has reflected a similar concern by respondents about groundwater availability. Participants in this study gave a high rating to industrial and household chemicals, gasoline and oil and fertilizers as pollutants compromising groundwater quality, and recognized the risk posed by fertilizers, insecticides and herbicides. The prominence of these pollutants was also true of the Holsman et al. study. Overall, this study differs from previous studies because its primary focus is on participants' perceptions and understanding of groundwater.

12. LIMITATIONS OF THE STUDY

Those who took the survey constituted a convenience sample of stakeholders with a greater interest in water issues and/or knowledge and understanding of groundwater and groundwater governance than members of the general public. Interpretation of the results should be made with the aforementioned demographics in mind. However, this does not imply that the results should be minimized since groundwater governance and policy must be made with these stakeholders in mind, and care should be taken to investigate the implications of groundwater policy on a population with different demographic characteristics. Central Texas residents who responded to the mail survey are a desirable sub-sample of all respondents to the survey. However, the response rate from these respondents was small relative to the response rate to the online survey. Given the small mail survey sample and the sampling method used, a difference of means and chi-square test was not conducted on the data collected.

The considerably lower response rate from those people surveyed by mail may reflect respondents who are less likely to have access to the internet, or socio-economic factors which may make them less likely to use the internet. However, the results from the online and mailed survey respondents are not appreciably different for the topics covered by the survey questionnaire.

13. CONCLUSION AND SUGGESTIONS FOR FUTURE RESEARCH

Texas residents are informed about the location of groundwater, but less certain which aquifers source their groundwater. They are more certain about the availability of groundwater to meet their current needs at the county and state level, but less certain about its availability to do so over the next 25 years. However, Texans place more responsibility on themselves to take actions to ensure adequate groundwater in times of scarcity. They favor scarce groundwater to be allocated to meet household needs but are concerned about groundwater allocations to meet the needs of agriculture, the natural environment and, to a lesser degree, groundwater management.

Although there is much public discourse and many strong feelings about buying and transporting water to meet groundwater needs, or storing groundwater for future needs, Texans do not place these as highly ranked options on their list. Limiting city growth is an often contentious and highly debated option as a plan for providing water in case of future groundwater scarcity. Urban planners and policymakers should take note that sampled state residents are divided about these two options. Central Texans who reside in communities where there may be more encroachment from growing urban areas are more favorable to this as an option, however. Sampled Texans are very clear about what land use practices and pollutants are the culprits responsible for groundwater pollution, but policymakers and groundwater managers should take note of the general public's dependence on public, private and commercial sources of drinking water.

Overall, the research conducted in this study should be considered exploratory and preliminary to a more extensive study of Texas residents. The connections between groundwater knowledge, perceptions and understanding, and community, industry, business and municipal behavior is a complex one. Texas residents might benefit from efforts, not just to educate them about groundwater, but also to bridge the gap between laymen's knowledge and scientific/expert knowledge about groundwater. This would address the uncertainty residents feel about groundwater availability as reflected in the 'I Don't Know' responses to the mail survey questions that offered this option and raise the profile of groundwater districts. The final question of the survey to both sets of participants was open-ended to allow respondents to make any comment about groundwater or groundwater management they chose. Although these comments were not included in this report, a qualitative analysis of such respondent feedback can provide insight into, and context for, the responses discussed in this report.

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