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Analysis of four governance factors on efforts of water governing agencies to increase water reuse in the San Antonio Region

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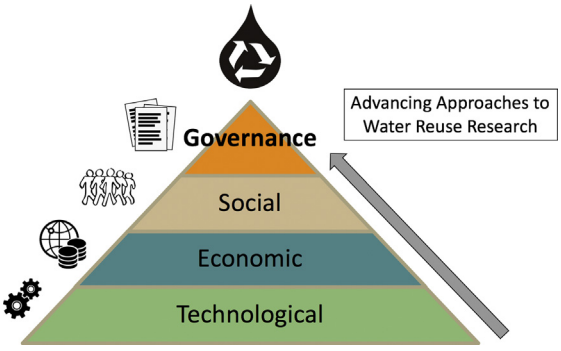
HIGHLIGHTS

- Water reuse has the potential to supply 24% of needed water in the San Antonio Region.
- Low reported efforts to increase water reuse by water governing agencies.
- Fifty-eight percent of agencies do not communicate with state water planners at all.
- Greater frequency in communication with state planners increases water reuse.

GRAPHICAL ABSTRACT



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ABSTRACT

Securing sources for water reuse and coordinating efforts of water governing agencies to do so are critical to realizing the potential of reused water to provide nearly 24% of the water demand of the San Antonio Region, defined as regions "L" and "K" by the Texas Water Development Board (TWDB). This research identifies key governance factors that contribute to increasing water reuse within the water planning sector and tests four governance-related hypotheses for their impact on efforts to increase water reuse in the Region. Variables tested include: the type and scale of water governance agency, the agency's frequency of communication with the TWDB, and the agency's familiarity with the TWDB water strategy supplies as defined in the Texas State Water Plan of 2017. A questionnaire addressing these variables was sent to water governing agencies in regions L and K; the response rate was 39.5%. Each variable was cross-tabulated with agency efforts to increase water reuse. Seven regression analysis models were calculated among the factors to test for statistical significance and impact on increasing water reuse efforts. Results indicate that nearly 70% of agencies in the regions have efforts to increase water reuse by as much as 10%. Among the tested hypotheses, frequency in communication with the TWDB was statistically significant for increasing agency efforts to reuse water. Results from these hypotheses are expected to help water managers identify key, governance-related factors that contribute to increased water reuse.

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1. Introduction

Rapidly growing population and semi-arid climate conditions combine to challenge state water planning agencies that are tasked with securing future water needs. Understanding the level of coordination, if any, existing between state and local water governing agencies could contribute to the development of effective, targeted policies for state and national water management. For example, the San Antonio Region of Texas, focus of this research, is faced with a rapidly growing population (U.S. Census Bureau, 2017a; U.S. Census Bureau, 2017b) and increasing drought. The Texas Water Development Board (TWDB) (the state's water planning agency) predicts that by 2020, the region will face an 11% gap between water demand and available water supply. It is further predicted that this gap will grow to nearly 44% by 2070 (Fig. 1), evidence of the strategy needed by water agencies in the region to plan for future water and resource availability. This research examines four hypotheses related to agency efforts to achieve the water reuse goals set by the TWDB for the San Antonio Region, to see if any are significant to contributing to water reuse.

The four hypotheses rely on the same dependent variable: the amount of effort invested by governing agencies toward accomplishing water reuse goals, as these are reported by the individuals working in those agencies. The research goal was to examine the relationships between the dependent variable and four separate, independent variables deemed to have potential for increasing water reuse efforts by the surveyed agencies. As suggested by previous water governance literature, the independent variables include familiarity with TWDB's water supply strategies, as reported in the 2017 Texas State Water Plan, frequency of communication with TWDB, scope of the agency's work, and type of agency.

2. Context of water planning and management in Texas

Texas water management and planning is important to understand as it frames the context for how other water governing agencies interact with the state board. The TWDB is the state water planning agency in Texas and is responsible to develop, manage, and conserve the state's water resources. The five-year state water plan is prepared in order to meet needs at municipal, rural, farm, business, and natural ecosystems levels (TWDB, 2017), and is a compilation of the sixteen Texas region's water plans. A water management strategy is a plan to meet a water need or potential shortage for a water user group (TWDB, 2017). Chapter eight of the 2017 Texas State Water Plan outlines the water management strategies for each planning region. In the planning process, each planning region evaluates feasible water management strategies for its anticipated water needs and recommends a final set of strategies, which are then reported to TWDB. Recommended strategies reflect need, location, cost, and available water sources of the region. If implemented, the recommended water management strategies of the 2017 report would provide 8.5 million acre-feet annually of additional water by 2070. Management "supply strategies" focus mostly on water conservation and include groundwater, seawater, surface water, and treated water, which alone has the potential to supply 14.2% of the water needed in Texas in 2070 (Fig. 2). This research focuses on the San Antonio area, comprised of Regions K and L. Plans from these two regions are meant to address the specific water needs for the area, which has significant water reuse potential, a rapidly growing population, and a projected gap between water supply and demand.

2.1. Water governance and water reuse in the Texas

At present, little research has been done on the level of coordination between local and state water governing agencies, thus, it is unknown. While TWDB is responsible to plan the state's water resources, the lack of research on coordination between the governing agencies, at state and local levels, makes it unclear how TWDB carries out the plans and accomplishes the goals prescribed in its five-year water plan.

For the San Antonio Region, a preliminary study of the governance of Water-Energy-Food Nexus for the San Antonio Region found nearly fifty water governing agencies with legal authority for managing water resources (Portney et al., 2017). These agencies include water service providers, wastewater service providers, storm water control districts, drainage districts, groundwater management areas, groundwater conservation districts, river authorities, other groundwater and surface governing bodies (Portney et al., 2017). The presence of this many agencies, often with similar responsibilities, in San Antonio raises concern about the level of coordination among them.

While TWDB lists water reuse as a high potential source, the degree to which other agencies make efforts to increase water reuse is unknown and begs the question: What is the effectiveness of a state planning agency if there is little communication of their plans to other, smaller agencies? Although TWDB advises the state on how to plan for water, the issue raised is how to coordinate with local agencies to ensure goals are implemented and procured. These questions define the aim of this research and seek to better understand the way in which factors between state and local water management governing agencies impact efforts to increase water reuse in the San Antonio Region.

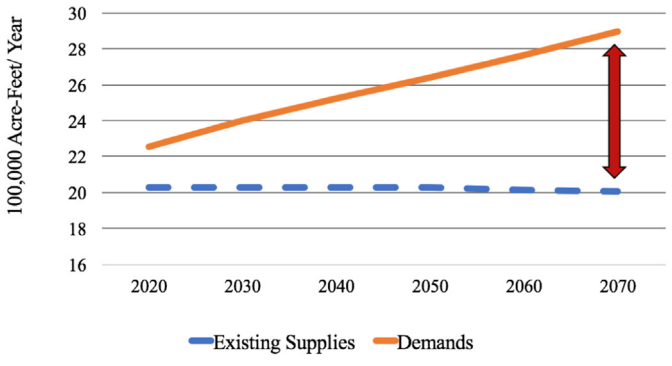

Fig. 1. Projected annual water demand and existing water supply in the San Antonio Region. The San Antonio Region will face a 44% water gap by 2070. (TWDB, 2017).

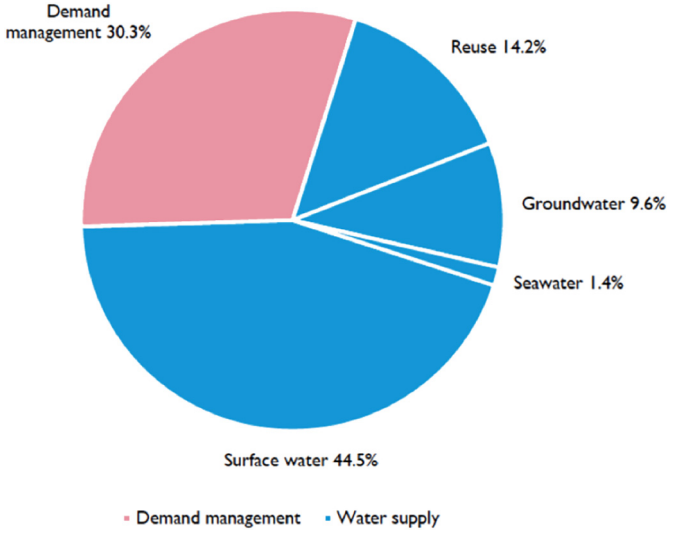

Fig. 2. Share of recommended water management strategies by water resource for Texas in 2070.
Source: TWDB's 2017 State Water Plan (TWDB, 2017).

3. Water needs and water reuse potential in the San Antonio Region

With a rapidly growing population in the region, the TWDB's 2017 State Water Plan indicates that water needed in this Region is expected to increase from 573, 634 acre-feet per year in 2020, to 995,247 acre-feet per year in 2070 (TWDB, 2017). Fig. 3 shows the projected water reuse supplies and water needs for the San Antonio Region, by decade. The percent of the region's water needs that water reuse strategy supplies are capable of filling are on average 24%.

TWDB plans to include five alternative sources of water to augment the region's needs: including increasing surface water resources, seawater desalination, demand reduction (through conservation and drought management), groundwater withdrawals and water reuse. Of these five sources, water reuse is the third largest expected supply and is anticipated to relieve nearly 18% of the region's water needs (Fig. 4). If water governing agencies in the region focus their efforts toward this state water goal, then TWDB's water reuse strategy has large potential to help satisfy the region's water needs.

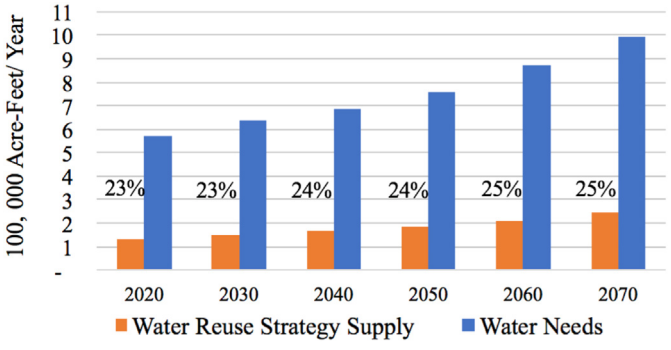

Fig. 3. Projected water reuse strategy supplies and needs for the San Antonio Region: water reuse strategy could supply 24% of the average water needs in the San Antonio Region (TWDB, 2017).

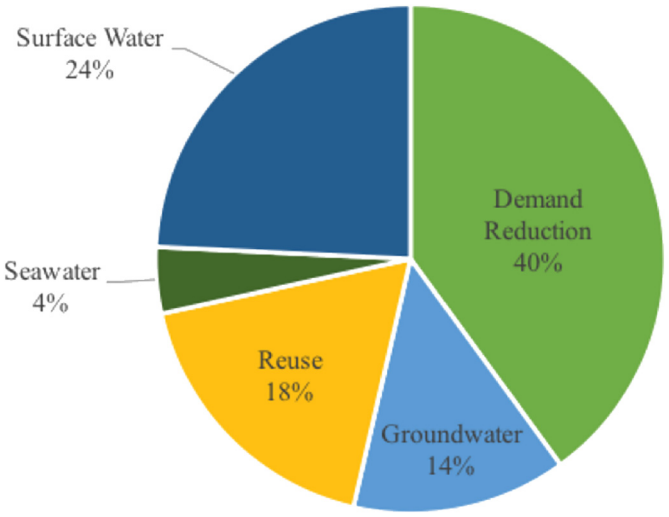

Fig. 4. Projected water sources for the San Antonio Region in 2070: 18% to be sourced from water reuse (TWDB, 2017).

4. Literature review

4.1. Past approach to water reuse: technological, economic, and social

In a field where technology and science have dominated the push for new sources of water, the importance of political science in expanding agency potential for increased water reuse must not be undermined. Technological advances in wastewater management and water reuse have come a long way in making reused water a viable, potable product. Past research highlights the technological advances in wastewater treatment (Adin and Asano, 1998; Fabres et al., 2017; Azis et al., 2017; Wen et al., 2015) and opened doors to make water reuse projects possible. Economic analysis of water reuse highlights the benefits of water reuse (Otoo et al., 2015), and provides cost-benefit analyses of switching to reuse from other sources (WateReuse, 2006; National Research Council, 2012). Federal, state, and local loans and grants have been adopted in an effort to support water reuse projects. Most recent research on water reuse has focused on social adaptation to water reuse, i.e. the effects of public acceptance in adopting water reuse technologies.

These three approaches are prominent in water reuse projects and have enabled communities in Texas, the United States, and across the globe to increase water reuse portfolios. While these technical, economic, and social breakthroughs aided the expansion of water reuse as a source of water, space remains for identifying additional ways to expand water reuse. The research done to date on the impact of governance on water reuse is minimal and varied in focus. Often local, regional and state water governing agencies minimally coordinate regarding shared water goals, including goals to increase water reuse. Research about ways to expand water reuse could benefit from improved understanding of this coordination (or lack thereof) between local and state water governing agencies regarding water reuse strategies and to identify those agencies with a greater potential for reuse. Fig. 5 depicts past and future approaches to water reuse research, with the specific goal of expanding water governance research. The emerging discipline of water governance is worth pursuing to discover potential means for increasing water reuse in given regions, a potential that may lie largely within the discipline of water governance.

4.2. Social approach: public acceptance of water reuse

Since the 1970's, the body of social-science knowledge focused on water reuse has targeted individual and community levels in addressing public acceptance of water reuse (Hurlimann and McKay, 2004; Hurlimann, 2007; Po et al., 2005; Lohman and Milliken, 1985; Jeffrey and Jefferson, 2003). The importance of the large body of knowledge surrounding public acceptance of water reuse is the identification of key variables that impact acceptance of water reuse: without community acceptance, water governing agencies would have a difficult time pushing for more reuse and makes understanding the attitudes of constituents and the factors influencing those attitudes a critical factor. While these household studies may be important to whether people can adapt their behaviors, they say little about the drivers of state or local policies calling for or supporting greater water reuse. Further research is needed to identify key variables that impact state and local agency water reuse efforts.

4.3. Water reuse policy and governance

A radically evolving field, such as wastewater treatment and reuse, often suffers from a lack of alignment between regulatory, legal, economic, public understanding, and public policy sectors (National Research Council, 2012). Most of the literature unravelling the social science and public policy aspects of water reuse highlight federal and state regulations applicable to water reuse; many of these have a water-quality focus. While the EPA has no formal reuse regulations, states are given primacy in water reuse policy. Legal literature on the topic notes that the current regulatory framework creates barriers to water reuse.

4.4. Assessing governance factors that contribute to reaching successful water management goals

Previous research focusing on water agency collaboration toward achieving shared water goals has typically aimed to understand factors

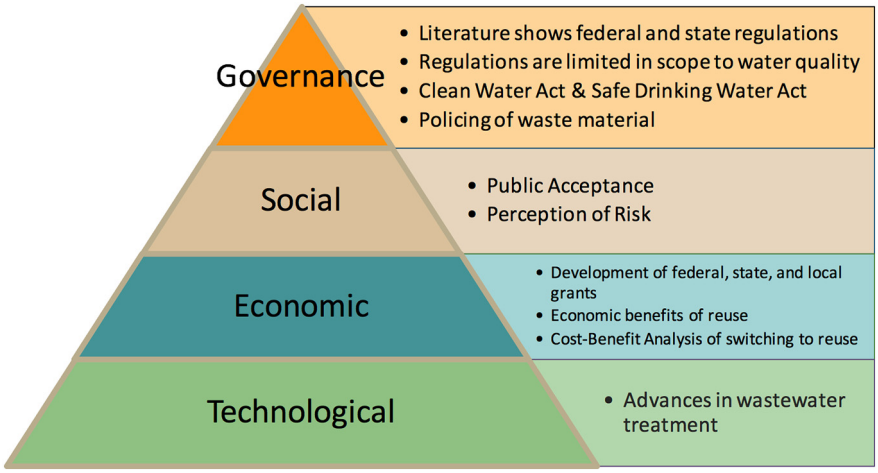

Fig. 5. Past and future research approaches to water reuse. Technological and economic approaches form the base of water reuse science, while more recent research on social acceptance of reclaimed water has contributed to the base of knowledge. Water governance research regarding water reuse is relatively new but has potential to contribute to increased water reuse.

that contribute to reaching these specific water-related goals. Three major case studies focused on unpacking the inter-complexities of water governance and assessing which governance factors lead to accomplishing regional targeted water management goals. These studies aimed at understanding single factors that contribute to accomplish shared goals.

Over the past decade these three studies have originated from across the globe and include China, Europe and the United States (California). Research aimed at exploring these factors have utilized questionnaire responses from stakeholders and water governing agencies to collect data for analysis (Huang et al., 2017; Newig and Fritsch, 2009; Lubell and Lippert, 2011).

Four predominant factors that impact an agency's ability to achieve shared water goals: the level of collaboration or cooperation with other water governing agencies, familiarity with high priority water policy, type of organizations involved, and the scale of governing agencies.

Collaboration/Cooperation: Lubell and Lippert (2011) surveyed California Bay Area stakeholders using questionnaires to assess the participation of Integrated Resources Water Management (IWRM) among stakeholders in helping them achieve integration goals. Collaboration among organizations did in fact aid in integrating IRWM practices.

Huang et al., 2017 used a Likert scale in questionnaire examining collaborative approaches to inter-agency water governance. In this case study, respondents reported on the intensity of cooperation between municipal departments of Dongguan using a scale of 1 to 7. Departments achieve only partial cooperation among departments.

Familiarity with Policy: In the study done by Huang et al. (2017), the level of familiarity among municipal departments was addressed by asking if they knew the policy interests of the most active water management governmental agencies in Dongguan.

Scale of Agency: Current environmental policies in Europe and North America promote collaboration at multiple governance levels as a means to reach more sustainable environmental policies and more effective, lasting policy implementation. In the research done by Newig and Fritsch (2008) geographical and multi-level governance scales are analyzed and considered for their impacts on environmental policy outcomes.

Type of Organization: the study done by Lubell and Lippert (2011), also assessed the achievement of IWRM goals by evaluating its success among the organizational types of water management agencies, and included the three most involved organizational types: NGO, local government, and water district.

5. Objectives and hypotheses

The objectives of this research are to (1) identify the type and scale of agencies central to contributing to water reuse in the San Antonio Region, (2) identify whether agencies are working to increase water reuse in the San Antonio Region. Taking into account previous water reuse literature, four hypotheses were developed to test for governance related factors that impact agency efforts to increase water reuse in the San Antonio Region.

Hypothesis 1. People that are more familiar with Texas Water Development Board's (TWDB) water supply strategies in the 2017 Texas State Water Plan are in agencies or organizations with greater efforts to increase water reuse.

Hypothesis 2. People in agencies that communicate more frequently with TWDB have greater efforts to increase water reuse.

Hypothesis 3. People in local scale agencies have greater efforts to increase water reuse compared to those in regional, and or state agencies.

Hypothesis 4. People working for water utility agencies have greater efforts to increase water reuse compared to private company, groundwater, river authority, research or extension, and state regulatory or planning agencies.

6. Methodology

6.1. Identification of water governance institutions and agencies

The first step in the research was to identify key, responsible water management and policy agencies in the San Antonio Region. The *Water Management in the San Antonio Region* study determined that most of the applicable organizations have jurisdiction within TWDB's Region L boundary, but also include organizations that seem relevant to water management in the San Antonio Region but are outside of the physical boundary. Thus, for this research, questionnaire responses from institutions and agencies whose jurisdictions either fit entirely within or have a portion within Region L and Region K boundaries are included making specific judgements for each. The questionnaire developed for the *Water Management in the San Antonio Region* targeted public officials and other individuals in institutions or agencies with some type of legal authority to make water management and policy decisions that affect water availability and quality in the region. While the larger project included 23 questions, this research used three questions to

analyze governance factors that impact increased water reuse efforts from agencies, as discussed above.

6.2. People in water governance and institutions and agencies

Once the relevant agencies were identified, individuals within them were identified to include each and every person within the organization whose position was relevant. In total, 289 individuals were identified using a variety of web-based sources and by placing calls to the agencies. A database containing the names and contact information for these people was created to prepare personalized mail merge files containing cover letters and mailing envelopes. The required IRB approval process was accomplished, certified, and included in the footer of the on line and the paper versions of the questionnaire.

6.3. The survey process

The cover letter indicated an option for each respondent to complete the questionnaire online; the online version was prepared using Qualtrics software under the Texas A&M institutional license and the URL was shortened to https://u.tamu.edu/water. The actual completion date of the questionnaire data was January 31st, 2018. The calculated response rate includes 101 completed questionnaires. Since 289 questionnaires were mailed, the raw response rate was calculated as 34.9%. However, the denominator for this calculation does not accurately reflect the size of the actual population surveyed. For example, 21 questionnaires were returned by the U.S. Postal Service as "undeliverable." Four people had left their respective positions, and 3 were on long-term leave from their position; one of the private water service providers had lost its certification, and four persons who had received questionnaires were ineligible to participate in the survey. Based on these results, an adjusted response rate was calculated as $101/(289 - 21 - 4 - 3 - 1 - 4) = 101/256 = 39.5\%$. A more accurate estimated response rate would also consider agencies included in the survey but having nothing to do with the San Antonio Region. In situations where an agency's jurisdiction boundary did not fit within or reach Region K or L planning areas, the respondents were disqualified from the survey population: 23 people were in this category. Thus, a third adjusted response rate was calculated as $101/(256 - 23) = 101/233 = 43.3\%$.

Fig. 6 illustrates the regional planning areas for the state of Texas and the combined Regions K and L, defining the "San Antonio Region" for this research. Web based research was used to verify whether an agency fit within the planning boundary of either Region K or L.

The specific criteria for a respondent's questionnaire to be considered within the San Antonio Region are:

- Jurisdiction of organization lies within or extends into TWDB Region K or Region L.
- Responses of "No", "Not in the San Antonio Region," or "Not Sure" to Q1: "Do you currently work for an agency or department that deals with water issues in the San Antonio Region?" were included if the area of jurisdiction fit within or extended into the Region K or Region L.
- For responses of "Yes," to Q1, area of jurisdiction was verified to fit or extend into the Region K or Region L for inclusion.

6.4. Statistical analysis

This study examined the effects of four independent variables upon the dependent variable: *agency efforts to increase water reuse*. STATA

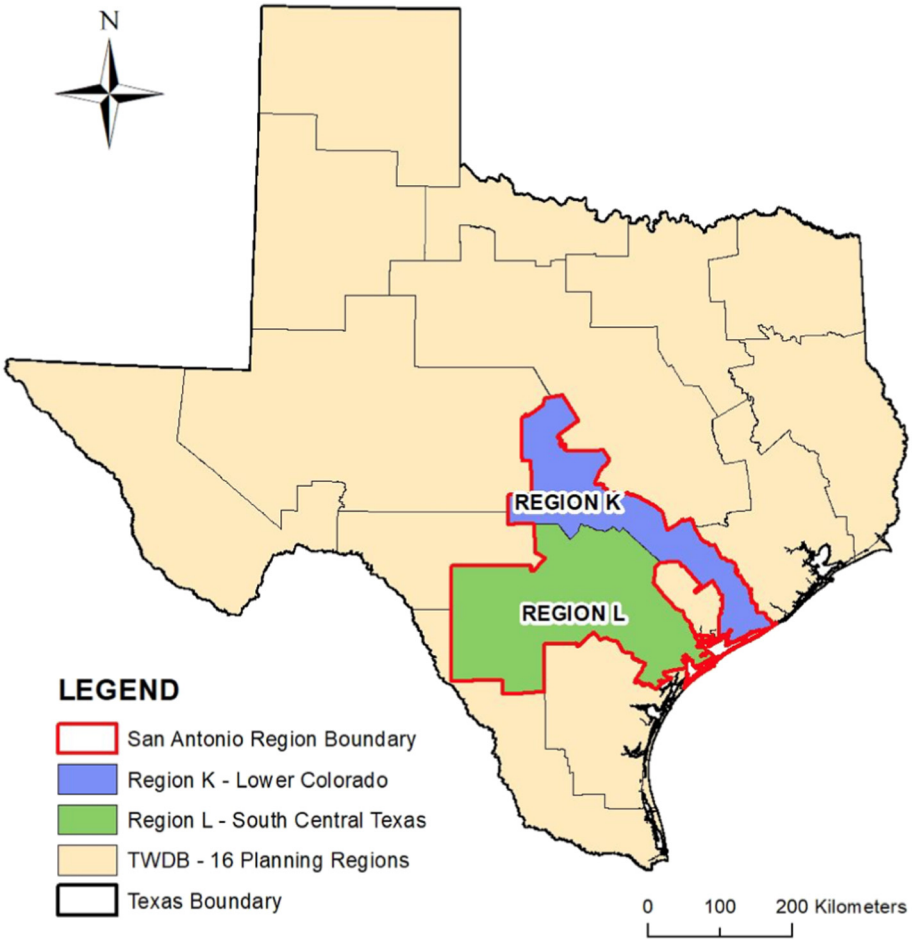

Fig. 6. Texas Water Development Board's regional planning areas. Region K and L combined define the boundary for the San Antonio Region.

statistical software was used to calculate a two-way table of frequencies between each hypotheses' independent variable and the dependent variable in order to identify whether an increase in the independent variable also increased the level of agency efforts to reuse water. Seven regression analysis models were run using STATA to test for statistical significance among all of the variables. The questions used in the survey to test each of the four hypotheses were:

Hypothesis 1: Increased *Familiarity with TWDB's Water Supply Strategies Impacts Water Reuse Efforts,* was tested to determine whether a higher familiarity level with the TWDB's water supply strategies in the 2017 State Water Plan correlates to agency efforts to increase water reuse. Two-way frequency tables were calculated using responses to Question 19 and Question 16 (Q16) shown below.

Question 19 (Q19) "*What percentage of the activities of your organization, agency, or department involves* ***efforts to increase water reuse*** *in the San Antonio Region"* addressed the dependent variable of agency efforts to increase water reuse was the dependent variable for this study. Response options were: 0–10%, 11–20%, 21–30%, 31–50%, 51–75%, or 76–100%. In Question 16 (Q16), "*How familiar are you with the Texas Water Development Board's* ***water supply strategies*** *for the San Antonio Region in the 2017 State Water Plan"* respondents used a Likert scale of 1–5 to select their level of familiarity, 1 for "Not at all familiar" and 5 for "Extremely familiar." Hypothesis 2, *Increased Communication with TWDB Impacts Water Reuse Efforts* was tested to determine whether the frequency of communication with the TWDB correlates to an agency's efforts to increase water reuse. Q19 (above) was cross-tabulated with responses to Q9 ("*Over the last year, as part of your job, how often have you communicated with any of these organizations, or decision makers from these organizations,* ***about water issues affecting the San Antonio Region****"*). The TWDB office in Austin, the Region K office, and the Region L office were listed agencies for respondents to select from regarding their frequency of communication: (1) Once a week or more, (2) Monthly, (3) Once every 3 months, (4) Once a year, (5) Not at all. To calculate the level of frequency in communication with TWDB as a single agency, an average of the respondent's level of frequency in communication with each TWDB office (Austin, Region L, and Region K) was used. Once averaged, the final value for frequency of communication with TWDB was rounded to the nearest whole number in order to fit within the 5 frequency bins identified above.

Hypothesis 3: *How Local Agencies Impact Water Reuse Efforts* was used to determine whether a local water agency contributes to the agency's increased efforts to reuse water. Responses from Q19 were cross-tabulated with coded responses from Q2: *What agency, organization, or department do you work for?* Based on responses, answers to these questions were coded as either 1 (local), 2 (regional), or 3 (state). Agencies categorized as local were those whose jurisdiction expanded to a city limit or smaller; those categorized as regional, included agencies whose boundary of jurisdiction expanded to at least a county level or larger; those categorized as state agencies, included those whose jurisdiction or management decisions applies to water anywhere within Texas.

Hypothesis 4: *How Utility Type Agencies Impact Water Reuse Efforts* first used the categorization based on the type of water management agency. Responses to Q2 determined the agency type (private/company, utility, groundwater, river authority, research/extension, and state regulatory/planning). A dummy variable was created for utility type agencies, and coded as 1 for utility and 0 for non-utility, which in this case, represents all other classification types of agencies. Hypothesis 4 was tested by cross-tabulating responses from Q19 with those from Q2, and then coded in their respective types of agencies. Those who reported that their agency was a utility, were coded as 1 (utility) or 0 (not utility).

Seven multiple regression analysis models were then computed using STATA statistical software to determine if a statistically significant linear relationship exists between the dependent and independent variables. See Table 1 for results of these 7 models of regression analysis.

7. Results

The results of this analysis indicate whether frequency in communication with the TWDB, familiarity with the strategy supplies, scale of an agency or type of agency contributes to an increase in water reuse efforts. Fig. 7 shows the percentage of water governing agencies that indicated their level of effort to increase water reuse. Overall, 69% of water governing agencies in the San Antonio Region use 0–10% of their efforts to increase water reuse, indicating that efforts to increase water reuse among agencies is low in the region.

7.1. Hypothesis 1

Fig. 8a shows the effect of the governing agency's level of familiarity with TWDB's water supply strategies upon the agency's efforts to increase water reuse in the San Antonio Region. Fig. 8a also shows low efforts to increase water reuse by agencies regardless of their level of familiarity with the water strategy supplies in the 2017 State Water Plan. Nearly 70% of agency respondents who indicated they were 'Not Familiar at All,' 'Slightly Familiar,' 'Moderately Familiar,' and 'Very Familiar' with the TWDB strategy supplies, also indicated their agency spends 0–10% of their efforts to increase water reuse.

7.2. Hypothesis 2

Fig. 8b shows how water governing agency's frequency of communication with TWDB affects the agency's efforts to increase water reuse. As agencies increase their level of communication with TWDB, their efforts to increase water reuse also increases. Eighty four percent of respondents from agencies who indicated they do not communicate with TWDB, spend 0–10% of their agencies efforts to increase water reuse. The percent of agencies with efforts to increase water reuse at 0–10% decreases as frequency in communication with TWDB increases.

Only one respondent indicated speaking monthly with TWDB, none indicated speaking once a week or more with TWDB. Fig. 8b therefore does not include the results for monthly communication, or once a week or more with TWDB.

7.3. Hypothesis 3

Fig. 8c shows the relationship between scale of the agency and efforts to increase water reuse in the San Antonio Region. State agencies do not have over 10% of their efforts to increase water reuse. Local and regional level agencies have more efforts to increase water reuse compared to state agencies.

7.4. Hypothesis 4

Fig. 8d shows the relationship between the type of water governing agency and efforts to increase water reuse in the San Antonio Region. Utility agencies show a greater variation of percent of efforts to increase water reuse compared to river authority and groundwater governing agencies. While water utilities reflect a greater variation in percent of efforts, river authorities overall, have a greater percent of agencies with efforts to increase water reuse beyond 0–10%.

Fig. 8d does not include respondents from private companies, research/extension, and state regulatory/planning agencies. Results show there were no agencies within the San Antonio Region boundary representing private companies, only two from research/extension, and five from state regulatory/planning. All of the respondents from research/extension and from the state regulatory/planning indicated their agencies had efforts of 0–10% to increase water reuse in the San Antonio Region.

Table 1
Seven regression analysis models of variables that impact agencies' efforts to increase water reuse in the San Antonio Region. Values in the table indicate regression coefficients for each variable.

Variables	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6	Model 7
Familiarity with TWDB's strategy supplies	0.139	0.189	0.136	0.127	0.127	0.127	0.129
	(0.190)	(0.188)	(0.185)	(0.191)	(0.191)	(0.191)	(0.190)
Frequency in communication with TWDB	0.836**	0.811**	0.841**	0.852**	0.852**	0.852**	0.862**
	(0.296)	(0.298)	(0.292)	(0.300)	(0.300)	(0.300)	(0.297)
Scale of agency	−0.981+	−0.533+	−0.666*	−0.587			
	(0.507)	(0.285)	(0.278)	(0.975)			
Type of agency: utility	−0.650			0.228	0.815	1.403*	−0.070
	(0.664)			(1.976)	(1.092)	(0.616)	(0.446)
Type of agency: groundwater		−0.190		0.249	0.836	1.423	−0.592
		(0.408)		(1.171)	(0.644)	(1.166)	(0.478)
Type of agency: river authority			0.662	0.842	1.429*	2.016+	
			(0.402)	(1.170)	(0.644)	(1.168)	
Scale of agency: local					0.587		
					(0.975)***		
Scale agency: regional						−0.587	
						(0.975)	
Scale agency: state							−1.430*
							(0.640)
Constant	2.136+	1.045+	1.166+	0.841	−0.920	−0.920	0.484
	(1.250)	(0.605)	(0.594)	(3.054)	(0.720)	(0.720)	(0.599)
Observations	60	60	60	60	60	60	60
R-squared	0.28	0.27	0.30	0.30	0.30	0.30	0.30
Adj R-squared	0.23	0.22	0.25	0.23	0.23	0.23	0.23
F	5.37	5.12	5.97	3.86	3.86	3.86	4.61

Note: Regression coefficients for each variable; standard errors in parentheses.
*** p < .001.
** p < .01.
* p < .05.
+ p < .10.

7.5. Summary statistics

Table 1 shows seven models of regression analysis on agency efforts to increase water reuse. The table includes the coefficient and standard errors for each model, and indicates whether the coefficient for a variable is statistically significant in increasing water reuse efforts. In the first of the four regression models three variables remained the same: familiarity with TWDB water strategy supplies, frequency in communication with TWDB, and level of agency. Model 1 includes the impact of a water governing agency being a utility on an agencies efforts to reuse water, model 2 includes the impact of a water governing agency being a groundwater agency on efforts to reuse water, model 3 includes the impact of a water governing agency being a river authority on efforts to re water reuse efforts, and model 4 includes the impact of a water governing agency being either a utility, groundwater agency and river authority on efforts to increase water reuse. Models 5–7 tests for the differences in scale of agency on efforts to increase water reuse. Model 5 includes the impact of a local on efforts to reuse water, model 6 includes the impact of a regional agency on efforts to reuse, Model 7 includes the impact of state agencies on water reuse. In each model, an agency's frequency of communication with TWDB was significant in increasing percent of efforts an agency spends toward increasing water reuse.

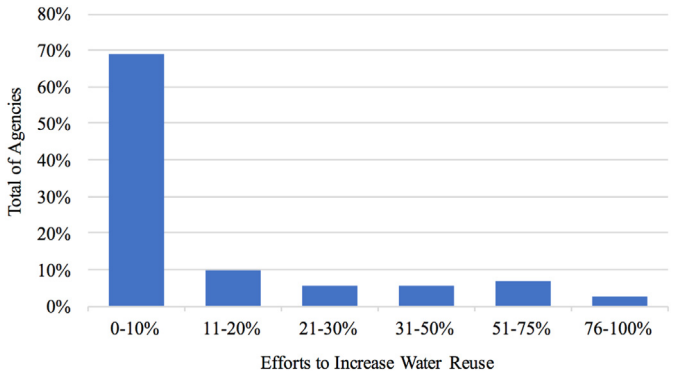

Fig. 7. Percent of agencies' efforts to increase water reuse in the San Antonio Region.

7.5.1. Familiarity with strategy supplies

The results of the regression analysis show a slightly positive correlation between familiarity with the water strategy supplies in TWDB 2017 State Water Plan and agencies' efforts to increase water reuse. The correlation coefficient between the two variables is 0.127 (see Model 4) showing a slightly positive correlation between them. The calculated p-value is .51, larger than .05, showing that the correlation between the two variables is not statistically significant (see Model 4). The correlation coefficient remains slightly positive in all seven models, and the p-value in all models indicates that familiarity with the TWDB's water strategy supplies remains insignificant. Therefore, we cannot reject the null hypothesis that people in agencies who are more familiar with Texas Water Development Board's (TWDB) water supply strategies in the 2017 Texas State Water Plan are not in agencies or organizations with higher efforts to increase water reuse.

7.5.2. Communication with TWDB

The results of the regression analysis show a statistically significant, positive correlation between frequency in communication with the TWDB and an agency's efforts to increase water reuse: the correlation coefficient between the two variables is 0.852 (see Model 4). The calculated p-value is .006, smaller than .05, showing that the correlation between the two variables is statistically significant (see Model 4). The correlation coefficient remains positive in all seven models, and the p-value in all seven models remains <.01 indicating that the frequency in communication with the TWDB is statistically significant. Therefore, we can reject the null hypothesis and conclude that people in agencies who communicate more frequently with TWDB do have greater amount of efforts to increase water reuse.

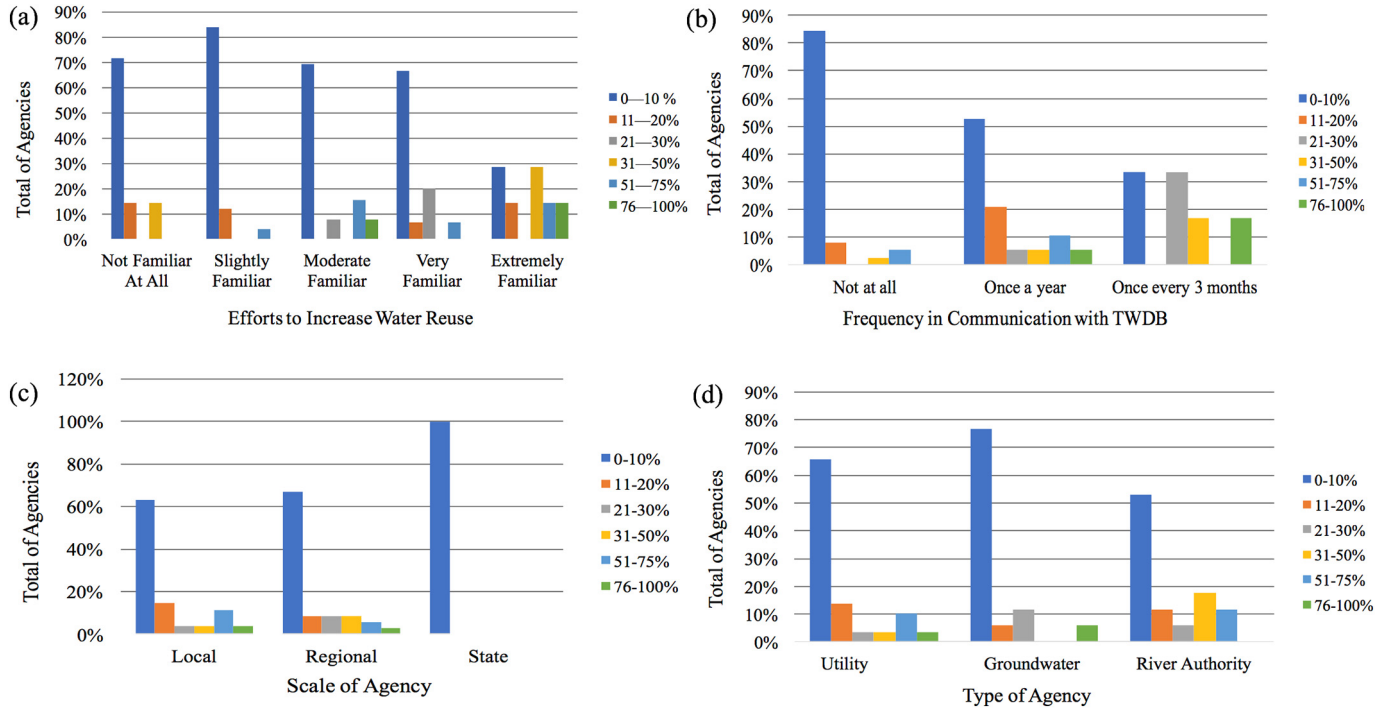

Fig. 8. (a) The effect of familiarity with TWDB's water strategy supplies in 2017 Texas State Water Plan on agencies' efforts to increase water reuse in the San Antonio Region. (b) The effect of frequency in communication with the Texas Water Development Board (TWDB) on agencies' efforts to increase water reuse. (c) The effect of scale of agency on agencies' efforts to increase water reuse in the San Antonio Region. (d) The effect of type of agency on agencies' efforts to increase water reuse in the San Antonio Region.

7.5.3. Scale of agency

The results of the regression analysis show a negative correlation between the scale of agencies and their efforts to increase water reuse. Model 5 does show that local agencies have more efforts to reuse water compared to those that are not local. The correlation coefficient for scale of agency varies in each model. Model 1 shows −0.981, model 2 shows −0.533, model 3 shows −0.666, and model 4 shows −0.587. In models 5–7, the significance of each scale of agency is tested. In model 5, the regression tests the level of effort to increase water reuse based on whether or not an agency is local, model 6 tests reuse efforts based on whether or not an agency is regional, and model 7 tests reuse efforts based on whether or not an agency is state. Model 5 shows a positive correlation of 0.587 on water reuse efforts based on whether or not an agency is local. Model 6 shows a negative correlation on reuse efforts based on whether or not an agency is regional, and model 7 shows a statistically significant negative correlation on water reuse efforts based on whether an agency is a state agency or not.

The results in model 5 best test for the hypothesis that local agencies reuse more water compared to non-local agencies. In model 5, there is a positive correlation of 0.587 for local agencies. The p-value is .55, larger than .05, indicating that the correlation between efforts to increase reuse and whether an agency is local or not is not statistically significant. We therefore cannot reject the null hypothesis that people in lower level agencies do not have greater amount of efforts to increase water reuse compared to those in regional, and/or state agencies.

7.5.4. Type of agency

The first four models of regression analysis best examine the impact of three different types of agencies on increasing water reuse efforts. In the first model the impact of a water utility on efforts to increase water reuse is tested. The correlation coefficient for a water utility type agency on water reuse efforts is −0.650, indicating a negative correlation. In the second model, the impact of an agency dealing with groundwater on efforts to increase water reuse is tested. The correlation coefficient between these two variables is −190. In the third model, the impact of an agency being a river authority on efforts to increase water reuse is tested. The correlation coefficient for these two variables is 0.622, indicating a positive correlation. In the fourth model, where all three types of agencies are considered, the correlation coefficient for water utility becomes positive and is 0.228; for groundwater type agencies, the correlation coefficient also becomes positive and is 0.249; and for river authorities the correlation coefficient increases to 0.842. None of the types of the agencies presented in the four models are statistically significant to increase water reuse.

In testing our original hypothesis if utility agencies have greater efforts to increase water reuse, we can look at model one. Again, the correlation coefficient is −0.650, and the p-value is .255, larger than .05, indicating the result is not statistically significant. We therefore, cannot reject the null hypothesis that people working for water utility agencies do not have greater amount of effort to increase water reuse compared to groundwater, river authority, research/extension, and/or state regulatory/planning agencies.

8. Discussion

Results show not all four hypothesis are supplemental to increasing agencies efforts to increase reuse. The discussion regarding the four hypotheses aims to explain why water reuse is not being pushed forward by certain agencies. Furthermore, the discussion of each hypotheses' impact is valuable as further research continues to better refine variables that impact agency water reuse.

8.1. Hypothesis 1—familiarity with strategy supplies

Since the water supply strategies in TWDB's 2017 State Water Plan are first recommended by user groups to TWDB, then reviewed by TWDB for approval, those who are 'Extremely Familiar' with TWDB's strategy supplies may be those agencies who submitted a water reuse strategy supply to the TWDB. Furthermore, since water strategy supplies are not required to be met, this would explain why agencies who ranged from 'Slightly Familiar' to 'Very Familiar' with TWDB's strategy

supplies mainly reused 0–10%. Had these water strategy supplies been implemented as goals mandated by TWDB (a top-down approach), then perhaps more agencies would have taken greater efforts to increase water reuse, especially if they had a water reuse target to meet.

8.2. Hypothesis 2—communication with TWDB

The TWDB provides funding to agencies for selected strategy supply projects through sources such as the State Water Implementation Fund for Texas (SWIFT). Therefore, agencies supporting water reuse projects may need to communicate more frequently with TWDB in order to secure funding to implement or continue their water reuse projects. As a result, agencies communicating more frequently with TWDB, may receive more funding with which to begin or continue in their efforts to increase water reuse.

8.3. Hypothesis 3—scale of agency

One explanation for why water reuse is not happening at the state scale, is because at this scale agencies are usually those who are planning and/or regulating local and regional efforts. State scale agencies are also ones that help fund local and/or regional water projects. Reuse is happening at the local level because local water utilities are often the distributors of reclaimed water.

8.4. Hypothesis 4—type of agency

Utilities have a greater range in efforts to increase water reuse, because these types of agencies may be as little as involved in the planning of water reuse projects with the regional planning group, to as involved in water reuse at the distribution line. Another explanation for their range in efforts is not all utilities are set up for water reuse projects. In fact, only one water utility, the San Antonio Water Systems indicated they reuse up to 76–100% of their efforts to increase water reuse.

It is almost expected that research and extension agencies wouldn't be much involved in water reuse because much of the technology supporting water reuse has been established. Furthermore, a low amount of effort to increase water by state planning and regulatory agencies would also be expected as these types of agencies are balancing their working efforts toward planning for future water needs through supply of groundwater, surface water, water conservation, water reuse, reservoirs, etc. and in regulating all the many uses of water.

Increased communication with TWDB increases agency efforts to reuse water. This is the only variable tested that is sufficiently statistically significant to assume its impact to increase water reuse efforts by agencies. Results of the questionnaire show that 58% of water governing agencies in the San Antonio Region do not communicate with TWDB at all. While the region is struggling to secure water, there is a level of expectation that there would be at least some level of communication among water governing agencies and the state planning agency, especially as water in the region is scarcely needing to be planned to meet the needs. This result showing a lack of communication, also indicates there is large potential for agencies to bridge this gap in communication. While there are many factors to consider regarding why agencies are not communicating with TWDB, these are not within the scope of this research, results here indicate that an increase in frequency of communication with the state planning agency, specifically for local agencies, will increase an agency's efforts to reuse water.

9. Conclusion

State planners and water managers faced with securing the water needed for the future of the region have identified new sources of water, but they face additional challenges to ensure water management agencies are cooperating toward the same water goals. While water reuse has the potential to supply nearly 24% of water needs in the San Antonio Region, the impact of securing this type of water, and coordinating water governing agencies to do so should not be undermined. As most literature on water reuse has focused on the technological, economic and social aspects, this research adds to the limited literature of water reuse governance. Among four tested hypotheses, agency communication with the state water planning board was statistically significant to increase water reuse in the region. Among those surveyed, response results show that 58% of agencies do not communicate with TWDB at all, signaling a high need to push water governing agencies to communicate. Given the R^2 of the seven regression models, the four hypotheses tested contribute to nearly 30% of factors contributing to increased water reuse. Therefore while these factors contribute to increased water reuse efforts by agencies, there is still a large margin for examining hypotheses alternative hypotheses. Further research is also necessary to explore the communication occurring between local, regional and state water governing agencies as they work together to secure water supplies for the future of their regions.

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