Governing the Water-Energy-Food Nexus: Solving a Common Pool Resource Challenge?

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Abstract

Emerging research from applied engineering and sciences has begun to develop fairly deep understandings of the connections between water, energy, and food/agriculture with an eye toward prescribing how to achieve greater efficiencies and to reduce the likelihood of resource depletion. Such research has documented the amounts of water used in producing energy and food; the amount energy needed to extract and transport water, and to grow, process, and transport food. What is far less well understood is how these resources are "governed," that is, how public policy and management decisions are made that affect these connections. Underlying the engineering and scientific research is an expectation that if the connections are better understood, policymakers will make better decisions that affect water, energy, and food -- decisions that will result specifically in more efficient use of water in producing food and energy. The expectation is predicated on the idea that decision making in water, energy, and food are "siloed" or "stovepiped," and that breaking down these silos will lead to policy and management decisions that achieve greater efficiencies. The central question animating this paper is whether and to what extent decision making in water, energy, and food can be said to be siloed, and if they are, whether there are conceptual reasons from public policy and management theory to suggest that breaking down these silos will make any different in terms of weakening the nexus between water, energy, and food. Preliminary results from a survey of water agencies and organizations suggests that there is very little interaction with agencies or organizations involved in energy and food decisions. To the extent that achieving greater nexus requires interactions, there is significant work to be done to re-think how public policy and management is organized and conducted.

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1. Introduction

As research on water-energy-food (WEF) systems nexus has advanced in recent years, the importance of understanding how the natural and human systems interact has become evident. Despite this, surprisingly little empirical research has been devoted to issues of food-energy-water systems governance, i.e. how (human) decisions about these (natural) resources are made and how decisions in one domain affect decisions and outcomes in the others. This paper represents an effort to advance a research agenda focused on WEF nexus governance. The purpose of this paper is twofold. First, it tries to crystalize a number of research questions that emerge from the natural systems nexus research, questions about policy and management decisions that have yet to be directly addressed. Second, it offers an approach to addressing these research questions with the hope that this approach will yield insights into how decisions affecting the nexus are made, and what these decision-making process imply for achieving results that are (apparently) desirable from a nexus perspective. It presents some preliminary data from a case study in the San Antonio region, selected because it presents a particularly salient site for investigating governance complexity in a highly fragmented multi-level context.

2. Key Questions in Nexus Governance

There is little question that in engineering and scientific fields, the idea of water-energy food nexus has gained great attention in recent years. Sometimes referred to as food-energy-water nexus (FEWS), scholars have conducted extensive analyses in an effort to understand the connections or relationships between these three domains. Without going into great detail, analyses have demonstrated that extracting energy resources (coal, petroleum, and natural gas in particular) and generating electricity use a lot of water. Of course, agriculture – growing and processing food – uses a lot of water. Growing, processing, and transporting food uses a lot of energy. And extracting, transporting, treating, and purifying water uses a lot of energy. Although these nexus issues all involve aspects of natural resources, they have never been explicitly discussed as important examples of common pool challenges, but the implications are difficult to ignore. In short, nexus research offers explanations for why particular resources become depleted. The implication is that water depletion occurs, at least in large part, because of energy and food/agriculture decisions. Energy sources are developed and perhaps depleted because of water and food demands.

Even if they have not been expressed explicitly, underlying the extensive nexus research are some assumptions or conclusions. These include assertions that sustainability requires greater efficiencies at the intersection of these domains, and that extracting energy resources and generating electricity must be done in ways that use less water, agriculture must grow food with less water, and so on. In short, nexus research seems to argue that breaking the linkages or connections across these domains is a desirable outcome.

From a governance perspective, it is not at all clear how or in what way water, energy, and food can be "conjointly" managed to produce this kind of outcome. Most theories of governance describe decisions and policymaking as taking place in silos, where water governance is largely independent of energy and food governance, and energy governance is independent of food governance.

Natural systems based research is not entirely silent on the issue of how to intervene on behalf of the nexus. Indeed, especially in a number of engineering fields, extensive work has been done to create "tools" that purport to help decision makers understand nexus issues. Underlying these tools is an assumption that managers and policymakers do not understand the linkages, that they in fact make decisions in one domain without regard for impacts in other domains, and that if they can be properly educated and informed, they will make better decisions, i.e. decisions about water that will require less energy, decisions about energy that require less require less energy, etc. Yet, of course, there is no theory of governance that would necessarily support such assumptions. And there are no theories of management, public of otherwise, that prescribe ways of conjointly managing these resources. Each of these assumptions deserves to be articulated as a research question.

RQ_1: To what extent do managers and policymakers in one domain (water, energy, and food) understand the importance of their decisions for the other domains?

RQ_2: To what extent do managers and policymakers in one domain make decisions without regard for impacts on the other domains? In other words, to what extent are decisions truly "siloed" or "stovepiped" in ways that work to the detriment of the other domains?

RQ_3: Does improved understanding of nexus issues alter the extent to which decisions in one domain respond to impacts on the other domains?

3. WEF Nexus Governance: The Case of San Antonio

The "region" that includes the Texas City of San Antonio presents a particularly salient location to examine nexus governance issues.[1] As discussed elsewhere, this region presents an extensive array of water, energy, and food/agriculture challenges. Just in terms of water, the city faces extreme shortages, and projections into the future suggest that these shortages will likely only get worse. Whether due to population growth, periodic drought, or increased demands from energy producers and electricity generators and the agricultural and food processing communities, or judicial mandates that the Edwards Aquifer not be depleted, San Antonio does not have access to the water it needs or will need in the years to come. From a governance perspective, San Antonio possesses institutional characteristics that make it a highly complex and fragmented context in which water, energy, and food are managed and policy is made. Of course, there are many state laws – statutory, case, and constitutional – that both constrain and enable decisions in the San Antonio region.

The institutional characteristics of nexus governance in the region include a large number of specific agencies at multiple levels of government. What becomes immediately obvious is that responsibility for nexus management and decision making seems extraordinarily complex and fragmented. Appendix A of this paper shows a list of the organizations and

[1] I use the term "region" here to convey the idea that the geographic area of relevance is larger than the city or its county. Pragmatically, the region consists of the geographic areas where the natural resources are, including the surface water (river ways), groundwater (aquifers), watersheds, natural gas and petroleum deposits, and farmlands.

institutions each of which has some amount of legal and formal authority for making decisions in each domain. In the water domain alone, there are at least 58 organizations with decision making authority at multiple levels of government. In energy, there are at least four organizations not including a number of the river authorities that have responsibility for generating and selling hydro-electricity, and in food/agriculture there are at least five organizations.

As an initial step in the process of delving deeply into the nature of public decision making related to the nexus, a preliminary study has been designed to elicit information from those people and agencies with **water authorities**, as outlined in Portney et al. (2017). During September 2017, a list of water managers and decision makers in the San Antonio region was compiled, consisting of 289 people in the organizations listed in the Appendix. A questionnaire was designed to ask respondents many questions about their roles, responsibilities, decisions, and interactions with other decision makers. As of the time when this paper is being written, there have been 66 responses. It is not possible at this early stage to know what the response rate is because of incomplete information concerning how many of the potential respondents received a questionnaire, how many were in some way inappropriate to have received a questionnaire, etc. What we do know at this point is that only twelve people explicitly refused to answer the survey.

The questionnaire, targeted to water decision makers, asked questions about frequency of contact with other water decision organizations, and with energy and food/agriculture organizations "over the last year." Included among these organizations are those whose primary role is as water and energy consumers and food/agriculture producers and processors. So while the survey was not distributed to those involved in energy or food decision making, questions do ask water decision makers about contacts with those in other domains. The full paper questionnaire is included in the Appendix. (Specifically, questions Q9c, e, h, Q10a-s, and Q11a-k were used to assess contacts with water agencies; questions Q15a, g, h, and i were used to assess contacts with energy agencies; and questions Q15j, o, p, q, and dd were used to assess contacts with food and agriculture agencies).

The survey used a multi-modal approach, as prescribed by Dillman et al. (2009). First, a mailing was prepared with a cover letter address by name to each potential respondent. This mailing included a paper questionnaire, a post-paid return envelope, and a post-paid postcard used to separately track those who responded. The letter offered an option to complete the survey online using a Qualtrics version that is nearly identical to the paper version. As of the writing of this paper, 34 respondents completed the questionnaire online, and 32 returned the paper questionnaire. No effort has been yet made to assess the representativeness of the resulting sample.

We can analyze the preliminary data to get a crude sense of the kinds of patterns related to the research questions presented earlier. Tables 1, 2, and 3 show some of these results. Table 1 shows the distribution of all 66 respondents according to the frequency of contacts with each of four types or groupings of water organizations. The first, the Texas Water Development Board (TWDB) is a state agency that has explicit legal authority for creating a state water plan every five years. Such plans use the best available information from many dozens of sources to estimate current and future water demands, and water sources and availability. These plans are conducted in 16 planning regions, one of which includes San

Antonio. So we would expect that just within the domain of water decision making, the respondents to the survey would have some high level of contact and interaction with TWDB. The second type of group is "any river authority." A number of rivers run through or around San Antonio, and the management of these rivers is statutorily given to these authorities or their associated river masters. The third type of group is "any other state agency" besides TWDB, including the Texas Council on Environmental Quality, the Texas Public Utility Commission, and others. To the extent that there is coordination between water decision makers and other agencies concerning environmental issues, we would expect significant interaction. Fourth, a category of "local agencies," and this mainly consists of decision makers in Groundwater Conservation Districts (GCDs) that have legal authority for managing and permitting groundwater resources including wells and withdrawals. Numerous GCDs, organized by non-overlapping geographic areas, cover the area of the San Antonio region. These local agencies also include municipal water providers, and the San Antonio Water System (SAWS) is the largest of these.

In Table 1, it is clear that the frequency of contact between respondents in water agencies and each of the four groups of other agencies is not especially high. Only 12.5% of respondents reported having contact with the TWDB more frequently than monthly; none of the respondents reported having frequent contact with any of the other three types of groups. The most frequent contact, overall, seems to be with the river authorities. If coordination, cooperation, or collaborative decision making within the water domain requires frequent contact, then this does not seem to happen even within this single domain.

Table 2 extends the analysis to the second nexus domain – energy. Here the respondents are separated according to which of the four groups of agencies they work in. The percentages show the self-reported extent of contact of people in each of these with decision makers in any of the energy agencies or organizations listed in the Appendix. Here we see that the vast majority of respondents from each type of organization have little or no contact with people from energy organizations. Indeed, only the TWDB seems to have much contact at all, and here only half of the respondents from TWDB report monthly to once yearly contacts with energy organizations.

Table 3 shows the frequency of contacts with food and agriculture organizations. Again, the results suggest that there is very little contact between water organizations and food or agriculture organizations. Across all four groups of respondents, the vast majority reported having little or no contact with any of the food organizations. This is perhaps somewhat surprising given the fact that food and agricultural production (farmers) represent one of the heaviest users of water in the region.

These preliminary results suggest that indeed water, energy, and food nexus governance does not exist. Decisions in each domain are likely siloed, precluding coordination, cooperation, or collaboration across them. Of course, this does not mean that decision makers in each domain completely ignore impacts in other domains. It is certainly possible that water decision makers understand their impacts on energy and on food, and incorporate this understanding into those decisions. In the absence of frequent contact, however, we would expect the efficacy of such incorporation to be minimal at best.

4. Moving Forward: Social Network Analysis to Study Water-Energy-Food Nexus Governance

The promise of the San Antonio survey is to produce adequate data to engage in formal social network analysis to provide much more detailed information about the connections between and among decisions makers. Network science and network analysis has long been used as a method of examining relational data and has recently emerged as an important tool in policy and governance sciences (Bernardo and Lubell 2016; Bernardo and Scholz 2010; Bernardo et al. 2015; Jansy and Lubell 2015; Lubell 2013). Social network analysis is usually associated with the creation of "maps" that depict types or strengths of relationships and transactions between and among people and organizations. Social networks are comprised of "nodes" and "ties," where the nodes are individuals or other social actors and the tie represents some relationship or transaction. The nodes and ties are compiled into an adjacency matrix and a graphical "map" which serve as the foundation of social network analysis. Many methods have been created to examine the structural nature of a given social network. For example, a structural analysis can examine the extent to which an overall network is densely or weakly connected. It can also identify the most centrally connected nodes, or nodes that are connected to these central nodes, among other things. Although the map represents a primary way of depicting social networks, the method has been constructed with the benefit of a wide array of metrics that provide systematic statistical measures of the nature of the nodes and ties. In the description below, we make reference to some of the metrics that we would expect to accompany different possible hypothetical maps in WEF nexus governance networks.

While initially social network analysis omits all qualitative or descriptive information, recent developments allow network analysts to incorporate actor characteristics into the analysis (Borgatti, Everett, and Johnson 2013). For example, a network comprised of individuals would benefit from integrating gender, age, and marital status. Within the WEF nexus framework, it may be useful to examine organizational size, age, geographic location, public private ownership, natural resource domain, etc.

Another important aspect of network analysis in natural resource governance is outlining or capturing potential flows of resources and information (Bodin and Crona 2009). For instance, gatekeepers often use their strategic location as a network broker to attain power or exert control over some resource. This behavior thwarts efforts to create efficient and sustainable communities. When present, network analysis can effectively identify holes or disconnections in the overall structure.

In addition to the individual connectivity characteristics, network analysis also measures aspects of the global, or overall, network. Measures of connectivity at the global level allows us to determine if the specific geographic area has a high or low level of connections which will influence strategic cooperation and collaboration on projects dealing with policy implications on natural resources. Thus, network analysis allows for analysis of relationships at the node level as well as the network level.

An underlying theme of WEF nexus research is the idea that connections and trade-offs must be better understood, and that decisions that affect the uses of one resource must take into consideration the impacts on the others (Scott et al. 2015). Indeed, the implicit goal of WEF nexus research is, arguably, coordination of these decisions such that the connections or trade-offs are minimized. We therefore suggest that effective governance of the WEF nexus

requires a high level of cooperation and coordination among decision makers, stakeholders, and managers (Kurian *et al*., 2017; Ansell and Gash 2008). Conversely, decisions made in one domain with no regard for impacts in the others inevitably yields suboptimal results.

An important use of SNA is to determine in any WEF nexus system the degree to which coordination actually seems to occur. Our expectation is that in most WEF, there is little or no coordination. We would expect to find that there are three individual networks representing the three domains of food, energy and water, and that these networks are largely disconnected from each other. Figure 4 captures the hypothetical image of a very compartmentalized or siloed version of the nexus governance network. There are three network domains in the Figure, one representing governance of water, another of food, and the third of energy. The blue squares would represent specific organizations within a defined geographic governance area and the red circles would represent categories of organizations. For example, we show a hypothetical organizational category called "Wastewater Governance," with two specific organizations, "Clean Water" and "Wasted h2o," key to this category of governance. The point is that when SNA is applied across all three domains, we expect to find very few inter-connections.

The siloed nature of the nexus governance network depicted in Figure 4 highlights the idea that the organizations and people involved do not frequently communicate, collaborate, or cooperate across domains. There are some interactions that are present within the nexus domains, but there is little interaction between domains. Empirically, a local nexus network could be even more disconnected than what is shown in Figure 4. As seen in Figure 4, there are some organizations in each division that correspond to two organization category types.

Figure 5 shows what a highly connected nexus governance network might look like. Here, organizations from each domain of the nexus seem to interact and cooperate, or are in communication with organization types in the other domains. There is much interaction between and within the nexus domains. From a nexus governance perspective, this hypothetical connected structure is presumably highly desirable in order to achieve high levels of resource efficiency. High levels of connectivity represents sharing of information, resources, and strategies to increase efficiency and sustainable practices. Similarly, consideration of trade-offs between resources (the subject of specific questions posed to all stakeholders) is likely to be present in highly integrated networks. In a highly connected network the transaction costs of resource trade-offs are expected to be reduced because there is more information and resources flowing through the network.

5. Organization of data and analytical tools that enable knowledge translation in support of evidence-based decision making

Network science recognizes the inherent and complex interdependencies that create the WEF nexus and provides means to examine relationships not only between individuals but also between individuals and organizations or institutions. The traditional approach to policy analysis and governance focuses on examining a single policy, policy domain, or phenomena at a single point in time. This approach treats multiple processes that occur simultaneously as a function of some decision-making agenda or leaves them wholly unresolved. In contrast to the singular approach, Lubell (2013) updated the Ecology of Games (EG) framework to address the institutionalized nature of policy-making. Essentially, the theory argues that there are multiple

policy actors and organizations that participate in the decision-making process, all existing within one geographically defined policy area. A policy game consists of policy actors that participate in a "rule-governed collective decision making process called a policy institution" (Lubell 2013: 538). Perhaps more important, the EG approach suggests that actors may well be engaged in policymaking in more than one domain simultaneously. To understand the decision making "game" for a given policy maker or organization, the roles that that policy maker plays in all domains is required. The EG framework and network analysis provides new insights to understanding governance strategies in the WEF nexus. Suffice it to say here that SNA promises to provide a means to examine the complexity of decision making networks even across policy domains.

The EG framework applied to nexus governance seeks to understand how governance networks operate within domains and across domains (Lubell and Henry 2010; Mewhirter et al. 2011). To achieve the kinds of efficiencies between water, energy, and food governance presumably requires a high degree of connectivity between networks (Scholz et al. 2008). If such connectivity exists, the EG framework posits that different decision making entities over water, energy, or food would ideally work simultaneously across natural resources within a geographically designated area. The question is whether or not these entities have any communication about what effect their behavior will have on other natural resources of the WEF nexus, or if these governance bodies cooperate in their respective requirements and duties.

SNA is typically conducted with benefit of information about how connected different organizations, stakeholders, and decision makers are (Leach et al. 2002; Lubell et al. 2012). While there are many ways that decision makers and stakeholders from water, food, and energy can interact, we propose to examine two specific connectivity behaviors -- interpersonal interactions and communications. For each individual involved in nexus governance, we would seek to determine how frequently interpersonal interactions and communications take place. For example, after assembling a comprehensive list of agencies, organizations, stakeholders, and decision makers in each policy domain, we would survey decision makers or agency informants and ask each of them a number of questions, such as:

- How often do you speak to a member of [water, energy, or food governance organization or agency]?

- How frequently do you communicate with individuals from the following [water, energy, or food governance organizations] about specific projects?

- In the course of doing your job, how frequently do you come into contact with other employees from the following [water, energy, or food governance organizations]?

The questionnaire

While the frequency of communication and interaction is a first step in identifying a connection within the nexus, SNA also seeks to take into consideration the content of individual

communication. This is accomplished by asking about specific kinds of communications or interactions. For example, the decision maker or informant may be asked:

- How frequently do you have meetings with [water, energy, or food governance organizations] about how to best manage water resources?

- How often do you or your organization collaborate with [water, energy, or food governance organizations] on energy conservation projects?

- Have you or your organization ever been involved with any of the following organization on a local planning commission that focused specifically on food, water, or energy?

The values from the survey questions are then used to create the network graph demonstrated below. While there are many metrics in the social network analysis toolbox that can be used to determine the extent of connectivity. Here, we highlight two of the most frequently used: centrality and density.

Centrality measures the extent to which individual nodes are connected to other nodes in the network. *Degree* centrality is a simple count of the number of ties each alter has. Degree is able to be analyzed as a directional (in-degree and out-degree) and non-directional, which have different implications in how information may flow through the network. Other measures of centrality, *eigenvector* and *closeness* for example, incorporate measures of the actors' connections into the measures. For example, eigenvector essentially measure the extent to which the focal actor is connected to other well-connected actors. Closeness measures how close, according to graph theoretic measures, each actor is to every other actor in the network. Both of these measures offer an effective measurement of how soon the actors may be made aware of information flowing through the network. All three measures will reveal how connected the actors are to their surrounding network,

Density is a more direct examination of the levels of connectivity in an interpersonal and global network. It is expressed as a ratio of the number of ties present to the number of potential ties. Density examines whether or not the actors connections are also connected to each other. In other words, a network is densely connected if actor A is connected to actors B, C, D and E, and actors B, C, D and E are also connected to each other. If actors B, C, D and E are not connected to each other there are low levels of network connectivity and high levels of brokerage or sparseness. This measure can also compute an overall density, or how connected the entire network is to each other. If all actors are connected to all other actors (a relatively rare occurrence) there will be high levels of connectivity in the overall network.

6. Beyond network descriptions: possible explanations for differences

Increasingly, analysis of nexus governance networks has sought to move beyond the network descriptions depicted in Figures 1 through 5. Specifically, analysis has turned its attention to understanding some of the conditions under which nexus governance networks are more or less connected. Are there examples of food-energy-water governance networks that are highly connected? What makes these networks connected when others are much less so? Theories of nexus governance have not advanced to the point where comprehensive

statements about these conditions can be made, but this paper proposes building on existing works to advance this task. Here we choose two specific characteristics that are thought to distinguish highly connected nexus governance networks from poorly connected networks, both developed by Kurian (2016). The first of these is the institutional "capacity" of organizations and agencies to work with others. We hypothesize that when organizations in a governance network possess high capacity (high amounts of resources, expertise, and other assets) they will be part of a governance network that is well-connected. When organizations in a network possess low capacity, they will be part of a governance network that is poorly-connected. We would expect that eigenvector and closeness centrality, as well as density in the map to be high, or show that network actors are well connected to other network actors.

A second characteristic, also rooted in the work of Kurian (2016), suggests that the extent to which a given nexus governance network produces effective trade-off decisions can be systematically measured. For example, Kurian develops an example of a "wastewater reuse effectiveness index" (WREI) that measures, for a given jurisdiction (usually a nation), an important policy outcome or result. What SNA promises to add to this analysis is the inclusion of a key explanation for why some jurisdictions seem better to produce high effectiveness while others produce lesser effectiveness. Our expectation is that better connected networks will produce higher levels of effectiveness. An example of this is shown in Figure 8, meant to convey the expected patterns of nexus governance where the WREI is high, i.e. where wastewater management is highly effective. In short, we expect that the nexus governance network will be highly connected (food, energy, and water governance are closely connected) where wastewater reuse is highly effective. The opposite expectation is depicted in Figure 9, where a poorly connected nexus governance network is associated with low WREI.

The fact is, however, that there are few theoretical grounds for prescribing any particular way of integrating decisions and producing better decisions across water, energy, and food. Social network theory and other social theories, such as bridging social capital, theories of public policy, theories of adaptive management, and others, offer snippets of such prescriptions. As the empirical analysis of water, energy, and food policy and management progress, greater effort will need to be made to make realistic and feasible recommendations concerning how to achieve more efficient and effective management of the key common pool resource, water. As the connections between among the various agencies is better understood, the expectation is that reforms will need to focus on the organization and definition of administrative responsibilities, with special attention to issues such as the legal authorities that enable and constrain the actions of the people who populate these agencies.

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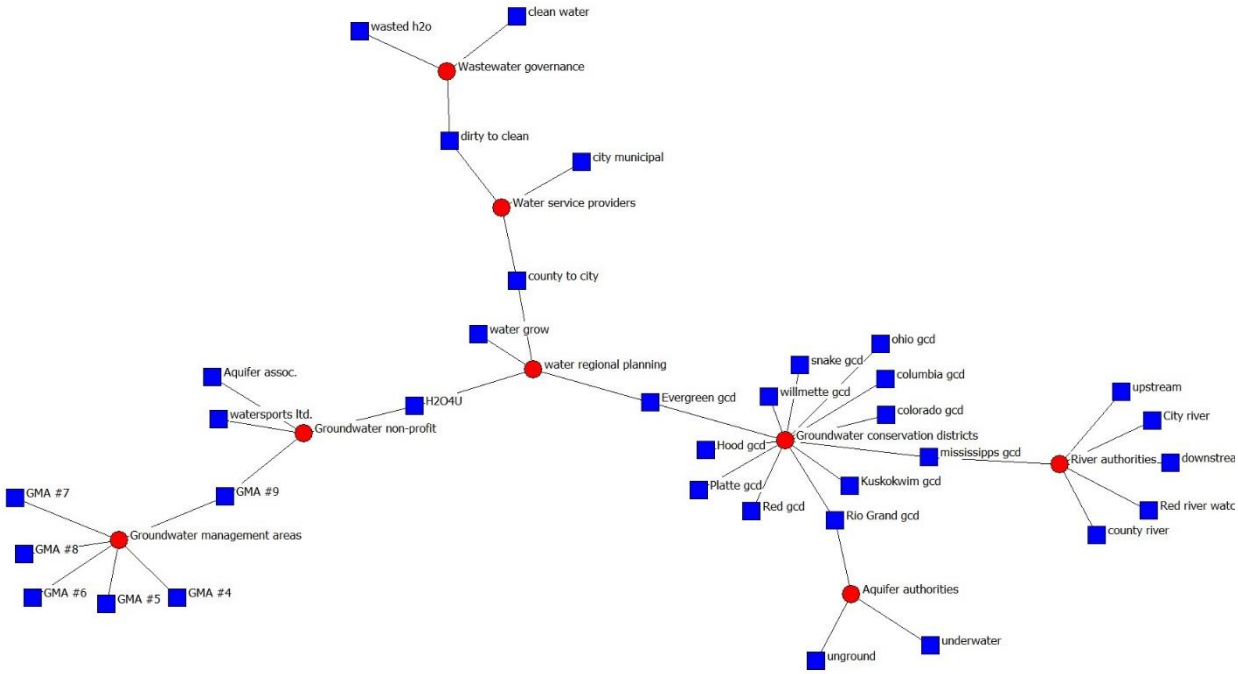
Figure 1: Example of Water Governance Network



For Figures 1, 2, and 3 we are primarily interested in node centrality and network cohesion. These values will reveal, a) Which nodes are highly connected to other nodes and b) to what extent the network as a whole is connected or disconnected. In a highly connected network we would expect to see high levels of, for example, network density which is a ratio of the total number of ties present to the total number of ties possible. Density ranges from 0 to 1 where highly connected networks have values closer to 1 and disconnected networks have values closer to 0.

Figure 2: Example of Energy Governance Network

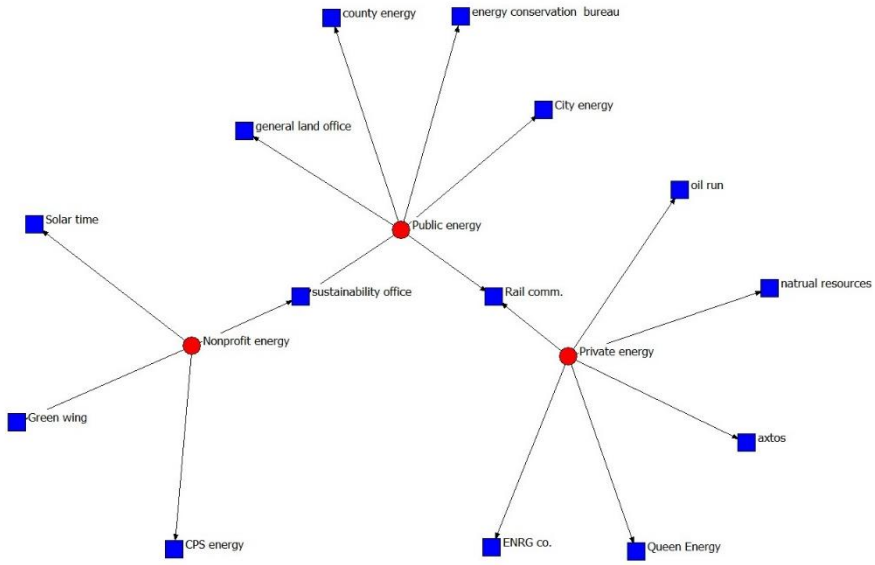


Figure 3: Example of Food/Agriculture Governance Network

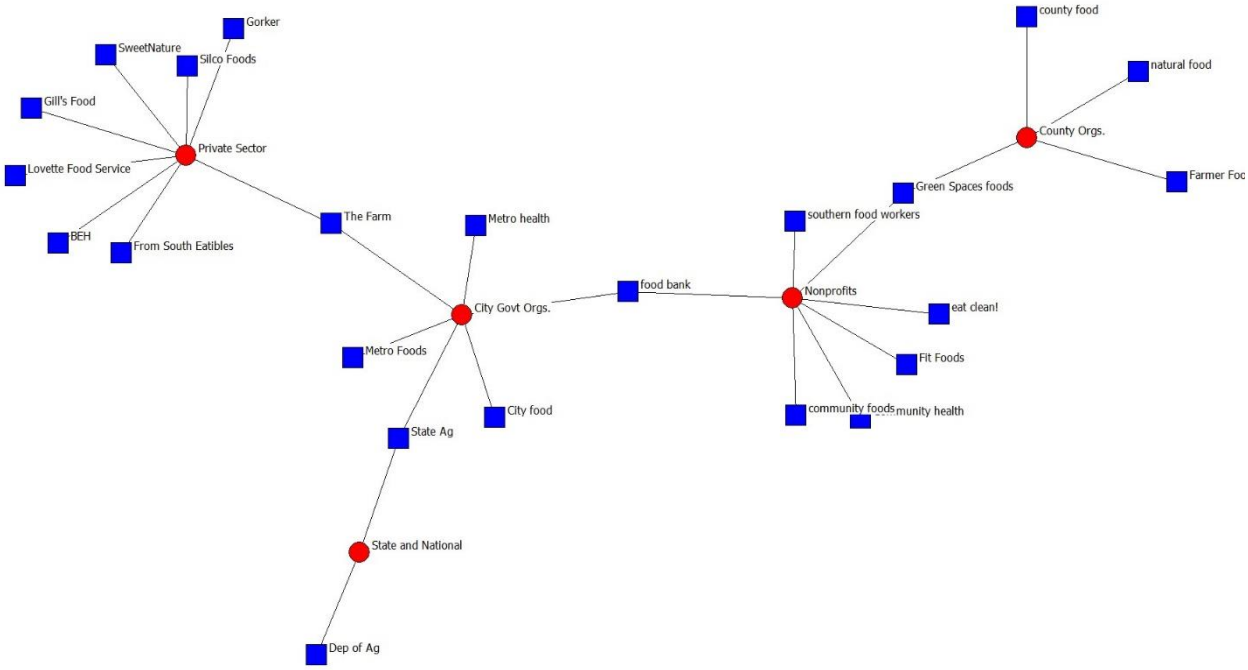
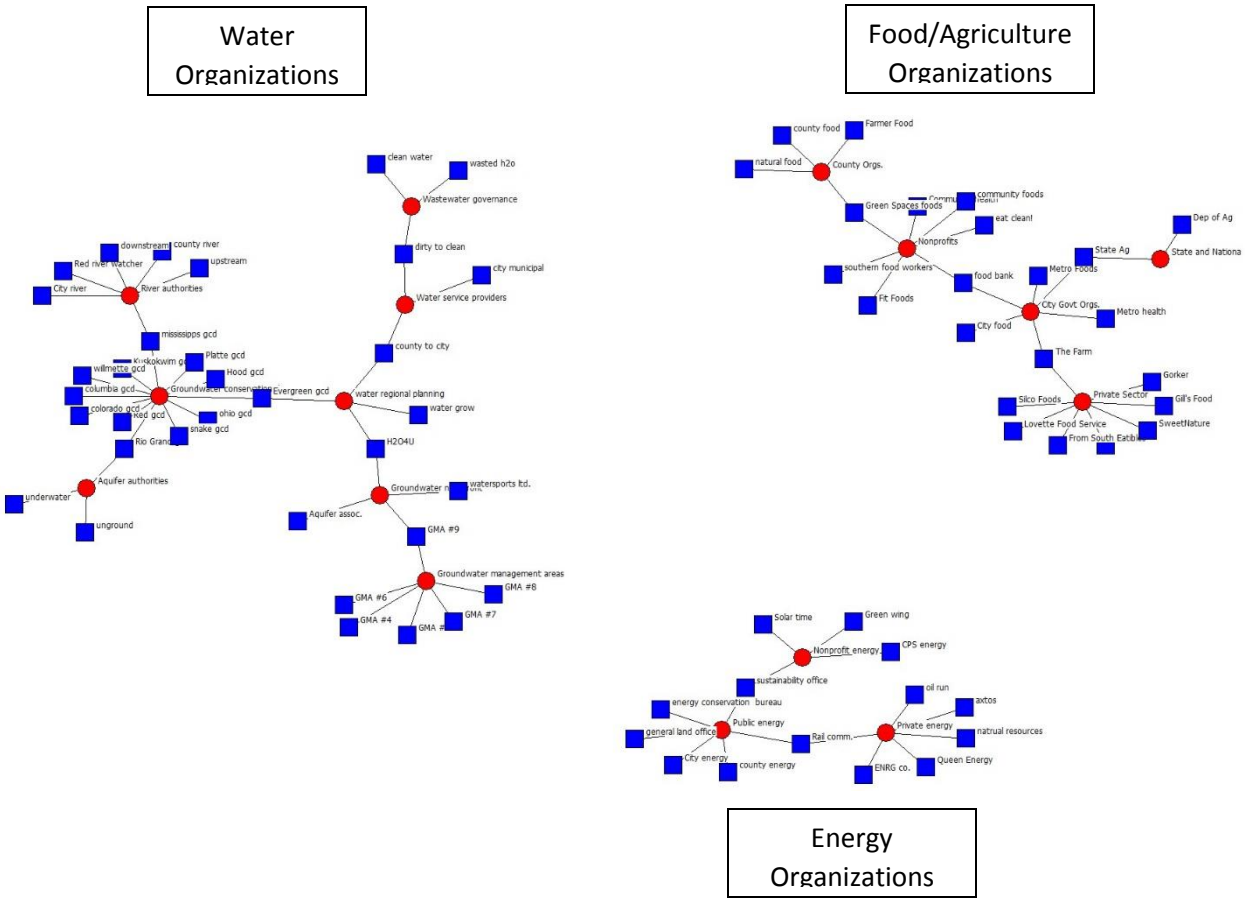
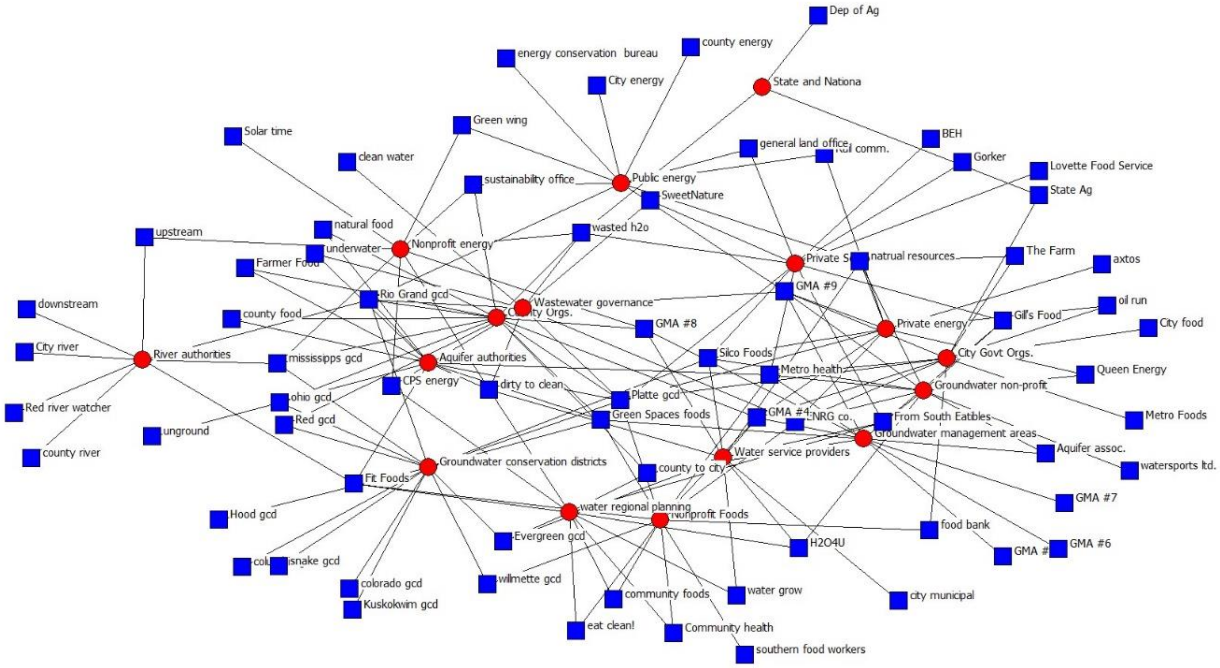


Figure 4: Example of WEF Governance Network that is “Siloed”



A simple metric of connectivity between nexus domains is a count of number of network components. Components are a number of disconnected, or siloed, portions of the network. When nexus networks are siloed we would expect to see a high number of components.

Figure 5: Example of WEF Governance Network that is “Coordinated”



Overall network density will provide information on the extent to which the observed level of connectedness is high or low in comparison to the potential level of connectedness, or number of potential ties.

Table 1: Frequency of all Respondents' contact with specific Water Agencies

	Contact with:			
	TWDB	Any River Authority	Other State agency	Any local agency
No contact	37.5%	9.1%	33.3%	50.0%
Monthly or less	50.0%	90.9%	66.7%	50.0%
More than monthly	12.5%	0.0%	0.0%	0.0%

Table 2: Frequency of contact of Water Agencies' Respondents with Energy Agencies or Organizations

	Contact with an **Energy** Agency or Organization:			
	TWDB	Any River Authority	Other State agency	Any local agency
No contact	50.0%	81.8%	66.7%	83.3%
Monthly or less	50.0%	18.2%	33.3%	16.7%
More than monthly	0.0%	0.0%	0.0%	0.0%

Table 3: Frequency of contact of Water Agencies' Respondents with Food/Agriculture Agencies or Organizations

	Contact with a **Food or Agriculture** Agency or Organization:			
	TWDB	Any River Authority	Other State agency	Any local agency
No contact	87.5%	63.6%	66.7%	100.0%
Monthly or less	12.5%	36.4%	33.3%	0.0%
More than monthly	0.0%	0.0%	0.0%	0.0%

Appendix: Water, Energy, and Food Organizations in the San Antonio Region

Water Decision Makers

- Edwards Aquifer Authority
- Three Irrigation Districts
- TCEQ Office in Austin
- TCEQ Freshwater Supply Districts
- Texas Water Development Board in Austin
- Texas Water Development Board Region K Office
- Texas Water Development Board Region L Office
- San Antonio Water System (SAWS)
- Live Oak Municipal Utility
- Canyon Regional Water Authority
- Two Stormwater or Flood Control Districts
- Texas Water Resources Institute in College Station
- Texas State Public Utility Commission
- Texas General Land Office
- Texas State Soil and Water Conservation Board, Region 2 Office
- South Texas Watermaster
- Edwards Aquifer Association
- Texas Alliance of Groundwater Districts
- Two Drainage Districts
- Bexar County Heritage & Parks Department
- Bandera County River Authority & Groundwater Conservation District
- Barton Springs/Edwards Aquifer & Groundwater Conservation District
- Blanco-Pedernales Groundwater Conservation District
- Comal Trinity Groundwater Conservation District
- Cow Creek Groundwater Conservation District
- Evergreen Groundwater Conservation District
- Gonzales County Underground Water Conservation District
- Hays Trinity Groundwater Conservation District
- Headwaters Groundwater Conservation District
- Kinney County Groundwater Conservation District
- McMullen Groundwater Conservation District
- Medina County Groundwater Conservation District
- Pecan Valley Groundwater Conservation District
- Plum Creek Groundwater Conservation District
- Post Oak Savannah Groundwater Conservation
- Uvalde County Underground Water Conservation District
- Alamo Soil & Water Conservation District #330
- Comal-Guadalupe Soil & Water Conservation District #306
- Wilson County Soil & Water Conservation District #301
- Brazos River Authority
- Central Colorado River Authority

Guadalupe-Blanco River Authority
Lavaca-Navidad River Authority
Lower Colorado River Authority
Nueces River Authority
Trinity River Authority
Trinity River Vision Authority
San Antonio River Authority
Upper Colorado River Authority
Upper Guadalupe River Authority
Groundwater Management Area #9 Office
Groundwater Management Area #10 Office
Hill Country Priority Area Office
Trinity Aquifer Priority Area Office
Joint Base San Antonio, Office of Water
Ozarka Spring Water Company

Energy Organizations and Agencies

ExxonMobil
Shell Oil
Valero
City Public Service (CPS) Energy
Duke Energy
Marathon Oil
Pioneer Natural Resources/Reliance Joint Venture
EOG Resources
Texas Railroad Commission
Texas Comptroller, Office of Energy Conservation
Texas Public Utility Commission
GE Power and Water, Inc.
Halliburton, Inc.
Association for Electric Companies of Texas
Blue Wing Solar, Inc.
Joint Base San Antonio, Office of Energy

Food and Agriculture Organizations and Agencies

Texas Farm Bureau
Texas AgriLife Extension Services
San Antonio Food Policy Council
San Antonio Food Bank
H.E.B., Inc.
Kroger, Inc.
NatureSweet Company, Inc.
Sysco Central Texas, Inc.
Labatt Food Services, Inc.

Del Norte Foods, Inc.
Cargill Food Distributors, Inc.

Cross-Cutting Organizations and Decision Makers

San Antonio Greenspace Alliance
San Antonio Mayor's Office
San Antonio City Manager's Office
San Antonio City Office of Sustainability
Bexar County Commissioners or County Manager
San Antonio Metro Health District
San Antonio Parks & Recreation Department
Office of Texas House Speaker Joe Strauss
Office of State Representative Lyle Larson
Office of Texas State Senator Carlos Uresti

Water Management in the San Antonio Region

Thank you for taking a few minutes to answer questions about water management and activities in the San Antonio Region. As noted in our cover letter, your answers will be held in the strictest confidence.

If you would prefer to answer the questions online with a computer or cell phone, please go to:

https://u.tamu.edu/water

Q1. Do you currently work for an agency or department that deals with **water issues in the San Antonio Region**?

◯ Yes ◯ No ◯ Not in the San Antonio Region ◯ Not sure

Q1a. If you answered "Yes" above, about what percentage of your time in a typical week do you currently spend working on **water issues of any sort**?

◯ 0-10% ◯ 11-20% ◯ 21-30% ◯ 31-50% ◯ 51-75% ◯ 76-100%

Q2. What agency or department do you work for?

Q3. What position do you currently hold in this department or agency?

Q4. Is your work full-time, part-time, or is it purely voluntary?

◯ Full-time ◯ Part-time ◯ Voluntary

Q5. About how many years have you spent in this current position?

◯ Less than a year ◯ 1-2 years ◯ 3-4 years ◯ 5 years or more

Q6. About how many years have you spent working for this department or agency?

◯ Less than a year ◯ 1-2 years ◯ 3-4 years ◯ 5 years or more

Q7. About how many years have you worked in any water-related field?

◯ Less than a year ◯ 1-2 years ◯ 3-4 years ◯ 5 years or more

Q8. Does any agency or department, including your own, conduct any type of **program performance review** of your agency? If so, how often?

◯ No program performance review ◯ Every other year ◯ Once a year ◯ Twice a year

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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**?

	Once a week or more (1)	Monthly (2)	Once every 3 months (3)	Once a year (4)	Not at all (5)	This is my own organization (6)
a. Edwards Aquifer Authority	◯	◯	◯	◯	◯	◯
b. Any Irrigation District	◯	◯	◯	◯	◯	◯
c. A TCEQ Office in Austin	◯	◯	◯	◯	◯	◯
d. Any TCEQ Freshwater Supply District	◯	◯	◯	◯	◯	◯
e. Texas Water Development Board in Austin	◯	◯	◯	◯	◯	◯
f. Texas Water Development Board Region K Office	◯	◯	◯	◯	◯	◯
g. Texas Water Development Board Region L Office	◯	◯	◯	◯	◯	◯
h. San Antonio Water System (SAWS)	◯	◯	◯	◯	◯	◯
i. Live Oak Municipal Utility	◯	◯	◯	◯	◯	◯
j. Canyon Regional Water Authority	◯	◯	◯	◯	◯	◯
k. Any Stormwater Management or Control District	◯	◯	◯	◯	◯	◯
l. Texas Water Resources Institute in College Station	◯	◯	◯	◯	◯	◯
m. Texas State Public Utility Commission	◯	◯	◯	◯	◯	◯
n. Texas General Land Office	◯	◯	◯	◯	◯	◯
o. Texas State Soil and Water Conservation Board, Region 2 Office	◯	◯	◯	◯	◯	◯
p. South Texas Watermaster	◯	◯	◯	◯	◯	◯
q. Edwards Aquifer Association	◯	◯	◯	◯	◯	◯
r. Texas Alliance of Groundwater Districts	◯	◯	◯	◯	◯	◯
s. Any Drainage District	◯	◯	◯	◯	◯	◯
t. Bexar County Heritage & Parks Department	◯	◯	◯	◯	◯	◯

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Q10. Over the last year, as part of your job, how often have you communicated with any of these specific organizations, or decision makers from these organizations, **about water issues affecting the San Antonio Region**?

	Once a week or more (1)	Monthly (2)	Once every 3 months (3)	Once a year (4)	Not at all (5)	This is my own organization (6)
a. Bandera County River Authority & Groundwater Conservation District	○	○	○	○	○	○
b. Barton Springs/Edwards Aquifer & Groundwater Conservation District	○	○	○	○	○	○
c. Blanco-Pedernales Groundwater Conservation District	○	○	○	○	○	○
d. Comal Trinity Groundwater Conservation District	○	○	○	○	○	○
e. Cow Creek Groundwater Conservation District	○	○	○	○	○	○
f. Evergreen Groundwater Conservation District	○	○	○	○	○	○
g. Gonzales County Underground Water Conservation District	○	○	○	○	○	○
h. Hays Trinity Groundwater Conservation District	○	○	○	○	○	○
i. Headwaters Groundwater Conservation District	○	○	○	○	○	○
j. Kinney County Groundwater Conservation District	○	○	○	○	○	○
k. McMullen Groundwater Conservation District	○	○	○	○	○	○
l. Medina County Groundwater Conservation District	○	○	○	○	○	○
m. Pecan Valley Groundwater Conservation District	○	○	○	○	○	○
n. Plum Creek Groundwater Conservation District	○	○	○	○	○	○
o. Post Oak Savannah Groundwater Conservation District	○	○	○	○	○	○
p. Uvalde County Underground Water Conservation District	○	○	○	○	○	○
q. Alamo Soil & Water Conservation District #330	○	○	○	○	○	○
r. Comal-Guadalupe Soil & Water Conservation District #306	○	○	○	○	○	○
s. Wilson County Soil & Water Conservation District #301	○	○	○	○	○	○

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Q11. Over the last year, as part of your job, how often have you communicated with any of these specific organizations, or decision makers from these organizations, **about water issues affecting the San Antonio Region**?

	Once a week or more (1)	Monthly (2)	Once every 3 months (3)	Once a year (4)	Not at all (5)	This is my own organization (6)
a. Brazos River Authority	◯	◯	◯	◯	◯	◯
b. Central Colorado River Authority	◯	◯	◯	◯	◯	◯
c. Guadalupe-Blanco River Authority	◯	◯	◯	◯	◯	◯
d. Lavaca-Navidad River Authority	◯	◯	◯	◯	◯	◯
e. Lower Colorado River Authority	◯	◯	◯	◯	◯	◯
f. Nueces River Authority	◯	◯	◯	◯	◯	◯
g. Trinity River Authority	◯	◯	◯	◯	◯	◯
h. Trinity River Vision Authority	◯	◯	◯	◯	◯	◯
i. San Antonio River Authority	◯	◯	◯	◯	◯	◯
j. Upper Colorado River Authority	◯	◯	◯	◯	◯	◯
k. Upper Guadalupe River Authority	◯	◯	◯	◯	◯	◯
l. Groundwater Management Area #9 Office	◯	◯	◯	◯	◯	◯
m. Groundwater Management Area #10 Office	◯	◯	◯	◯	◯	◯
n. Hill Country Priority Area Office	◯	◯	◯	◯	◯	◯
o. Trinity Aquifer Priority Area Office	◯	◯	◯	◯	◯	◯
p. Ozarka Spring Water Company	◯	◯	◯	◯	◯	◯
q. ExxonMobil	◯	◯	◯	◯	◯	◯
r. Shell Oil	◯	◯	◯	◯	◯	◯
s. Office of Texas House Speaker Joe Strauss	◯	◯	◯	◯	◯	◯
t. Joint Base San Antonio	◯	◯	◯	◯	◯	◯
u. Valero	◯	◯	◯	◯	◯	◯
v. Any Professional Hydrologist or Geologist	◯	◯	◯	◯	◯	◯
w. Office of State Representative Lyle Larson	◯	◯	◯	◯	◯	◯
x. Office of Texas State Senator Carlos Uresti	◯	◯	◯	◯	◯	◯

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Q12. Over the last year, as part of your job, have you personally participated in any kind of **stakeholder forum or cooperative planning effort** with organizations or agencies other than your own?

◯ Yes ◯ No ◯ Not sure

Q12a. If you participated in any stakeholder forums or planning efforts over the last year, please provide the **names or types** of up to three of these. About how many times did you participate in each type of forum or planning effort over the last year?

	Once (1)	Twice (2)	Three times (3)	More than three times (4)
1. Name or type of forum or organization #1_____ _____	◯	◯	◯	◯
2. Name or type of forum or organization #2_____ _____	◯	◯	◯	◯
3. Name or type of forum or organization #3 _____ _____	◯	◯	◯	◯

Q12b. Thinking about the three forums or organizations you listed, did any of these discuss or otherwise address issues of water used for extracting or producing **energy or electricity**?

◯ Yes ◯ No ◯ Not sure

Q12c. Did any of the three forums or organizations you listed discuss or otherwise address issues of water used for **food, farming, or agriculture**?

◯ Yes ◯ No ◯ Not sure

Q13. Overall, how concerned are you about **future water availability** in the San Antonio Region?

0 Not Concerned at all	1	2	3	4	5	6	7	8	9	10 Extremely Concerned
◯	◯	◯	◯	◯	◯	◯	◯	◯	◯	◯

Q14. How important do you think **water conservation** is in the San Antonio Region today?

◯ Very Important ◯ Moderately Important ◯ Not Very Important

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Q15. Over the last year, as part of your job, about how often have you communicated with organizations, or decision makers from these organizations, **about any issues affecting the San Antonio Region**?

	Once a week or more (1)	Monthly (2)	Once every 3 months (3)	Once a year (4)	Not at all (5)
a. City Public Service (CPS) Energy	◯	◯	◯	◯	◯
b. Duke Energy	◯	◯	◯	◯	◯
c. Marathon Oil	◯	◯	◯	◯	◯
d. Pioneer Natural Resources/Reliance Joint Venture	◯	◯	◯	◯	◯
e. EOG Resources	◯	◯	◯	◯	◯
f. San Antonio City Office of Sustainability	◯	◯	◯	◯	◯
g. Texas Railroad Commission	◯	◯	◯	◯	◯
h. Texas Comptroller, Office of Energy Conservation	◯	◯	◯	◯	◯
i. Texas Public Utility Commission	◯	◯	◯	◯	◯
j. Texas Farm Bureau	◯	◯	◯	◯	◯
k. San Antonio Mayor's Office	◯	◯	◯	◯	◯
l. San Antonio City Manager's Office	◯	◯	◯	◯	◯
m. Bexar County Commissioners or County Manager	◯	◯	◯	◯	◯
n. San Antonio Metro Health District	◯	◯	◯	◯	◯
o. San Antonio Parks & Recreation Department	◯	◯	◯	◯	◯
p. San Antonio Food Policy Council	◯	◯	◯	◯	◯
q. San Antonio Food Bank	◯	◯	◯	◯	◯
r. H.E.B.	◯	◯	◯	◯	◯
s. Kroger	◯	◯	◯	◯	◯
t. NatureSweet Company	◯	◯	◯	◯	◯
u. Sysco Central Texas, Inc.	◯	◯	◯	◯	◯
v. Labatt Food Services	◯	◯	◯	◯	◯
w. Del Norte Foods, Inc.	◯	◯	◯	◯	◯
x. Cargill Food Distributors	◯	◯	◯	◯	◯
y. Blue Wing Solar, Inc.	◯	◯	◯	◯	◯
z. San Antonio Greenspace Alliance	◯	◯	◯	◯	◯
aa. GE Power and Water	◯	◯	◯	◯	◯
bb. Halliburton	◯	◯	◯	◯	◯
cc. Association for Electric Companies of Texas	◯	◯	◯	◯	◯
dd. Texas Department of Agriculture	◯	◯	◯	◯	◯

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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?

Not at all familiar (1)	Slightly familiar (2)	Moderate familiar (3)	Very familiar (4)	Extremely familiar (5)
◯	◯	◯	◯	◯

Q17. Please indicate **how much potential** you think each strategy listed below has for managing water to help the San Antonio Region meet its water needs over the next 50 years?

	Very low potential (1)	Low potential (2)	Moderate potential (3)	High potential (4)	Very high potential (5)
a. Conservation of Irrigation Water	◯	◯	◯	◯	◯
b. Build a New Reservoir	◯	◯	◯	◯	◯
c. Municipal Water Conservation	◯	◯	◯	◯	◯
d. Indirect Water Reuse	◯	◯	◯	◯	◯
e. Direct Water Reuse	◯	◯	◯	◯	◯
f. Drought Management	◯	◯	◯	◯	◯
g. Aquifer Storage and Recovery	◯	◯	◯	◯	◯
h. Seawater Desalination	◯	◯	◯	◯	◯
i. Groundwater Desalination	◯	◯	◯	◯	◯
j. Direct Potable Water Reuse	◯	◯	◯	◯	◯

We have a small number of questions about you, your job and the organization, agency, or department you work for.

Q18. About what percentage of your time in a typical week do you spend **working directly on activities** that help your organization achieve its primary mission?

◯ 0-10% ◯ 11-20% ◯ 21-30% ◯ 31-50% ◯ 51-75% ◯ 76-100%

Q19. What percentage of the activities of your organization, agency, or department involves **efforts to increase water reuse** in the San Antonio Region?

◯ 0-10% ◯ 11-20% ◯ 21-30% ◯ 31-50% ◯ 51-75% ◯ 76-100%

Q20. What is your gender? ◯ Male ◯ Female

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Q21. Please select all of the categories that best describe your background.

White (1)	Black or African American (2)	American Indian or Alaska Native (3)	Asian (4)	Latino (5)	Native Hawaiian or Pacific Islander (6)	Other (7)
◯	◯	◯	◯	◯	◯	◯

Q22. What is the highest level of schooling you have completed to date?

◯ Less than a high school diploma
◯ High school diploma or equivalent (e.g. GED)
◯ Some college, no degree
◯ Associates degree (e.g. AA, AS)
◯ Bachelor's degree (e.g. BA, BS)
◯ Master's degree
◯ Professional degree
◯ Doctorate degree

Q23. Is there **any other information** that you can share with us about water-related issues that you have been involved in over the last year or so? If so, please provide a brief description or assessment below.

Again, thanks for taking the time to answer these questions. When completed, please return this questionnaire in the self-addressed stamped envelope and return the postcard separately to:

Prof. Kent Portney, Director
Institute for Science, Technology and Public Policy
Texas A&M University
TAMU 4350
College Station, Texas 77843-4350

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