Building a simple general model of municipal water conservation policy for communities overlying the Ogallala Aquifer

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Building a *Simple* General Model of Municipal Water Conservation Policy for Communities overlying the Ogallala Aquifer[1,2]

Abstract

On the nation's largest aquifer live 2.3 million people, most of whom depend on the Ogallala's water for household consumption, as well as for agricultural and industrial use. As the Ogallala's levels decline, policies need to be developed to encourage conservation of this resource that are a) efficient and effective and b) are politically feasible. Using results from a survey of nearly 3,000 residents, we reveal and elucidate community attitudes in the region regarding water use and various conservation policies. The results indicate an overall awareness of the problem and willingness to accept certain restrictions on water use and price changes, within limits.

I. Introduction

This project started as a result of a smaller study investigating constituent attitudes toward water pricing and regulatory measures in several urban and rural West Texas municipalities.[3] What that study found was there is little evidence that pricing strategies designed to encourage conservation would be rejected outright by those residents. When combined with current regulatory policy, a comprehensive strategy that includes price rationing by municipalities in this

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[2] Many thanks to Tara Wade and David Sullivan for their technical support on this paper.

[3] R. Gary Pumphrey, Jeffrey A. Edwards, & Klaus G. Becker. *Urban and rural attitudes toward municipal water controls: A study of a semi-arid region with limited water supplies*. *65* ECOL ECON 1-12 (2008), doi:10.1016/ j. ecolecon.2007.11.013.

area of the United States would certainly be a more effective prescription for conserving water than the current policy.

Commonly-implemented facets of regulatory policy, such as limits on water usage that affect lawn watering, car washing, as well as fines for over-use, waste, etc., are costly to enforce as they distract police and water department officials from more important duties, and adds to the workload of a community's court system. Regulatory policy can also be easily circumvented (e.g., someone with a privacy fence may water their grass before the prescribed time of day), and does not encourage conservation from those that are not affected by the policy (e.g., someone that does not have a car is not affected by a car washing restriction).

On the other hand, a price rationing approach which involves simply increasing the price of water to reduce usage is far less costly to enforce as no oversight is needed when the source is metered, circumvention is costly or impossible, and all users are affected regardless of property or vehicle ownership status. Furthermore, overuse and waste is unlikely on a large scale because if priced high enough, the cost of water becomes a conscious factor in one's financial welfare.

The problem is that most communities eschew pricing in favor of regulatory measures as a means of attempting municipal water conservation. Anecdotal evidence (collected by this team of researchers from anonymous city officials in many of the study communities) suggests that support for these measures by the public is generally high because they are most likely viewed as temporary in nature, and coincide with what the public sees as an appropriate response to what is typically a crisis situation. Elected officials, however, are hesitant to ask the public to pay more for the resource as it is assumed that voter discontent would be the result. In essence, many suggest that while it is political suicide to ask the public to pay more for a resource that they view as critical to their health and livelihoods, forcing constituents to use less water through legal restrictions is deemed less so. What Pumphrey, et al.[4] found by a phone interview process was that the public would not wholly reject the need for a pricing mechanism to enhance water conservation when needed. This study builds upon that one, but with a few twists.

The current study, funded by the National Science Foundation, Human and Social Dynamics Competition,[5] also tries to determine the most acceptable strategy, but covers a much larger area with far more interviews conducted, and also attempts to ascertain constituent attitudes toward the agricultural and ethanol industries. Specifically, while both studies focus on communities that overlie the Ogallala aquifer in the High Plains region of the United States, the seed study investigated only 6 communities in an area of approximately 4,700 square miles in the northwestern portion of Texas, while the current study covers parts of 8 states and some 174,000 square miles. Furthermore, the previous study analyzed survey results from about 800 individuals while the current study surveys nearly 3,000 people in 29 communities. In both studies there are questions evaluated to determine constituent attitudes toward pricing and regulatory measures, while the current research adds questions to try to determine attitudes toward the agriculture and ethanol industries in this part of the country. The agriculture industry alone is responsible for about 95% of all groundwater withdrawn from the Ogallala aquifer, and thereby is in direct competition with municipalities for this quasi-finite resource.[6]

Yet, despite increasing the geographic heterogeneity of the survey group, a surprising homogeneity in responses was the norm. What this study found was that during periods of drought, the most popular form of municipal water conservation is indeed a regulatory response;

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[4] See Pumphrey, et al., *supra*, note 3.

[5] This is a three and one-half year project with a completion date of February 2012. HSD Award BCS # 0826778.

[6] Peter Scholle & M. Lee Allison, Energy and Natural Resources Testimony presented to the SENATE COMMITTEE ON ENERGY AND NATURAL RESOURCES. High Plains Aquifer Coalition, (2003), http://www.kgs.ku.edu/ Hydro /HPAC/Testimony/ scholle.html.

however, a near unanimous indifference exists for temporary price increases during these periods. In fact, in only 5 of the 29 communities did the constituents disagree (in a statistically significant sense) with this conservation option. On the other hand, while there was near unanimous support against a more permanent, but arbitrary, price increase, about 60% of the respondents indicated that they would accept a 25% increase resulting in a substantial decrease in the quantity of water demanded. In fact, this seemingly small increase in municipal water prices would cause about 40% of the population in these communities to reduce their consumption. There was also near unanimous consent that some regulatory measures can even be implemented on a permanent basis. Support such as this probably indicates observations by members of the community that water is being wasted in such a way that the permanent implementation of a regulatory measure would be an appropriate response. For instance, assume that you frequently observe lawn sprinklers on automatic timing devices watering lawns during rain showers. As a concerned citizen, you may then see the need for a permanent regulatory measure that prohibits the use of sprinklers during periods of rainfall and/or a policy that makes it mandatory for new sprinkler systems to have a rain sensor.

With regard to peoples' views on the agricultural and ethanol sectors, our results indicate that about 92% of the constituents view the agricultural industry as important to their communities, and about 40% view the ethanol industry as important. Yet despite the overwhelming economic dependence upon these industries, the majority of constituents in 9 of the 29 communities surveyed would charge farmers for *all* of the water they use for irrigation while the members of 18 other communities are split on this notion—only citizens of 2 communities would reject outright full payment for irrigation water. Furthermore, the majority of people in all 29 municipalities believe that ethanol facilities should pay for all of the water they use in the ethanol distillation process.

What these findings tell us is that communities that depend on the Ogallala aquifer for their drinking water will *not* revolt if temporary price increases are implemented during periods of drought, and could accept a permanent 25% increase in the price of their water which would result in a substantial reduction in quantity demanded within these communities. And even though the above-mentioned constituents are profoundly aware that they are inherently tied to agriculturally-related industries, they also believe that farmers are not charged sufficiently for their irrigation needs and should probably play a larger role with water conservation in this area of the country.

II. The High Plains and the Ogallala Aquifer

The study area overlies the Ogallala aquifer, covering 174,000 square miles in parts of eight states (Colorado, Kansas, Nebraska, New Mexico, Oklahoma, South Dakota, Texas, and Wyoming), and has a population of 2.3 million. The aquifer is located in the U.S. High Plains region, which is part of the larger Great Plains region. The focus of this study is on 29 communities in the eight states that overlie the Ogallala aquifer. The common link between these communities is that some portion of the municipal drinking water supply originates as groundwater from the Ogallala in all 29 towns, as described by Scholle and Allison,[7] and Dennehy.[8]

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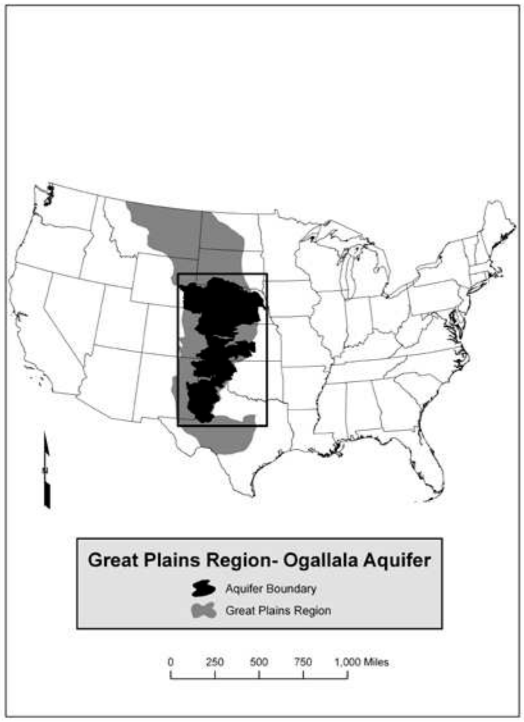
[7] Gutentag, et al., *Geohydrology of the High Plains Aquifer In Parts of Colorado, Kansas, Nebraska, New Mexico, Oklahoma, South Dakota, Texas, and Wyoming* GEOL SURV PROF PAPER 1400-B (1984), *available at* http://pubs.er.usgs.gov/djvu/PP/pp_1400_b.djvu.

[8] Kevin F. Dennehy, *High Plains Regional Ground-Water Study* (2000) GEOL SURV #091-00, *available at* http://co.water.usgs.gov/nawqa/hpgw/factsheets/DENNEHYFS1.html.



The High Plains study area is located east of, and in the rain shadow of the Rocky Mountains, meaning a majority of the region is semi-arid. It is characterized by a high, fairly flat, treeless plain with grasslands, prairie, farmland, along with some rolling topography. Annual rainfall increases as one travels east from the Rocky Mountains. The western portion of the study area receives less than 16 inches of rainfall annually and is considered a semi-arid or a mid-latitude dry continental climate; the far eastern portion has a more humid, continental climate that averages as much as 33 inches.[9]

The Ogallala aquifer, often referred to as the High Plains aquifer, is the largest water-bearing underground formation in the U.S. It has long been the principal aquifer in the region, as agriculture, municipalities, and industry all rely heavily upon the groundwater for irrigation,

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[9] U.S. Geological Survey, Ground-Water Resource Program (High Plains Water-Level Monitoring Study) (2010), http://ne.water.usgs.gov/ogw/hpwlms/physsett.html.

livestock production, domestic and industrial uses. Recently, the ethanol industry has begun to increase production in the Great Plains, which will put even more stress on the aquifer. As of June, 2010, there were 33 operational ethanol plants located in the study area, with a majority of the plants concentrated in the Nebraska and Kansas area (three other plants are under construction as of December 2010 according to RFA).[10]

This region has become a very productive and important agricultural area because of the presence of the aquifer and its large reserves of stored groundwater. The Ogallala is one of the most intensely pumped aquifers in the United States, supplying the region with what amounts to almost 30% of all groundwater that is used in the entire U.S. for irrigation. And while irrigation for agriculture accounts for almost 95 percent of the groundwater pumped from the Ogallala, just over 80% of the population in this area depend on the Ogallala for their everyday water needs, as Scholle and Allison,[11] and Dennehy[12] explain.

Water levels started to decline as soon as large scale pumping began in the 1930's and 1940's (this period is commonly referred to as "predevelopment," although some experts consider predevelopment to extend into the 1950's and 1960's in certain regions).[13] Estimated annual recharge to the Ogallala ranges from a meager 0.02 inch per year in the southwest portion to 6 inches per year in the northeast region of the aquifer.[14] In most areas overlying the aquifer, withdrawals from the aquifer have significantly exceeded natural recharge, thus the majority of the aquifer is considered nonrenewable. In essence, the Ogallala aquifer is being "mined," meaning water is being withdrawn at a rate much greater than recharge. From predevelopment to

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[10] Renewable Fuels Association (RFA), Biorefinery Locations webpage (2010), http://www.ethanolrfa.org / bio-refinery-locations/.

[11] See Scholle & Allison, *supra*, note 6.

[12] See Dennehy, *supra*, note 8.

[13] Luckey, et al., *Water-Level and Saturated-Thickness Changes, Predevelopment to 1980, in the High Plains Aquifer in Parts of Colorado, Kansas, Nebraska, New Mexico, Oklahoma, South Dakota, Texas, and Wyoming* (1981) GEOL SURV HYD INV ATLAS #HA-652, *available at* http://pubs.er.usgs.gov/djvu/HA/ha_652_plt.djvu.

[14] See Gutentag, et al., *supra*, note 7.

1980, water levels dropped as much as 100 to 200 feet in parts of southwestern Kansas, Oklahoma, and Texas.[15] McGuire[16] estimates the water level change "…from predevelopment to 2007 ranged from a rise of 84 feet in Nebraska to a decline of 234 feet in Texas." From predevelopment to 2007, approximately 13 percent of the aquifer had more than a 25 percent decline in saturated thickness.[17]

III. Corn and Ethanol Production in the High Plains area

The Energy Policy Act of 2005 mandated a Renewable Fuels Standard (RFS) for U.S. fuel production and was amended by the 2007 Energy Independence and Security Act. It calls for an increase in the annual amount of ethanol that is to be mixed with gasoline (and sold in the United States) from 4 billion gallons in 2006, to 7.5 billion gallons by 2012.[18] Historically, Congress has approved fairly substantial subsidies to biofuel producers and blenders, thus ethanol production capacity has steadily increased since 2005. As of December, 2010, Congress extended the tax incentives for ethanol production and use for one year.[19] Estimates are that U.S. ethanol production capacity will soon be in excess of 12 billion gallons, which is well above the 2012 standard.[20]

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[15] See Luckey, et al., *supra*, note 13.

[16] V. L. McGuire, *Water-Level Changes in the High Plains Aquifer, Predevelopment to 2007, 2005-06, and 2006-07*(2009). Ground-Water Resources Program GEOL SURV SCI INV REP # 2009-5019 at page 5, *available at* http://pubs.usgs.gov/sir/2009/5019/pdf/sir2009-5019.pdf.

[17] *Id.*

[18] Brent D. Yacobucci & Randy Schnepf, *Selected Issues Related to an Expansion of the Renewable Fuels Standard (RFS): CRS Report for Congress, Congressional Research Service,* Order Code RL34265 (2007), http://fpc.state.gov/documents/organization/98150.pdf.

Kevin C. Dhuyvetter, et al. *The U.S. Ethanol Industry: Where will it be located in the future?* Agricultural Issues Center University of California, Agricultural Marketing Resource Center (2005), *available at* http://www.agmanager.info/agribus/energy/Ethanol%20Industry(AgMRC)--11.25.05.pdf.

[19] Renewable Fuels Association, *Senate Passes Bill Extending Key Ethanol Tax Incentives* (2010), http://www.ethanolrfa.org/news/entry/senate-passes-bill-extending-key-ethanol-tax-incentives/.

[20] Paul Westcott, *U.S. Ethanol Expansion Driving Changes Throughout the Agricultural Sector* . AMBER WAVES, September 5 (4) (2007), http://www.ers.usda.gov/AmberWaves/September07/Features/Ethanol.htm.

The sole source of water for irrigation in most areas overlying the Ogallala aquifer is groundwater. As mentioned above, the climate in a majority of the Great Plains region is semi-arid, and precipitation during the growing season in most of the study area is not sufficient for substantial crop production, thus irrigation is necessary. As of 2007, 98 percent of biofuels production facilities (biorefineries) in the U.S. used corn as their main feedstock.[21] As of September, 2010, all but one biorefinery in the study area used corn as their feedstock.[22] Corn production in the study area can take as much as double the amount of water as cotton, wheat or sorghum. In 2003, the U. S. Department of Agriculture (USDA) National Agricultural Statistics Service (NASS),[23] the National Research Council[24] and O'Brien et al.[25] estimated that approximately 750 to 800 gallons of irrigation water are needed in northwest Kansas and Nebraska corn production for every gallon of ethanol produced. This translates into 5.4 trillion gallons of water needed just for ethanol production alone.

Keeney and Muller[26] in conjunction with the Institute for Agriculture and Trade Policy (IATP) estimated a 254 percent increase in the amount of water used in U.S. ethanol production in the eleven year period from 1998 to 2008 (using data on biorefineries that were scheduled to start production by 2008). Studies have shown that biorefineries use anywhere between 3 and 7 gallons of water per gallon of ethanol produced. That means the typical ethanol production

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[21] See Yacobucci, *supra*, note 18.

[22] See RFA, *supra*, note 10.

[23] U.S. Department of Agriculture (USDA), National Agricultural Statistics Service (NASS) (2004). 2003 Farm and Ranch Irrigation Survey, http://www.agcensus.usda.gov/Publications/2002/FRIS/tables/fris03_28. pdf.

[24] National Research Council *Water Implications of Biofuels Production in the United States. Committee on Water Implications of Biofuels Production in the United States, Water and Science Technology Board* (2007), http://www.nap.edu/catalog/12039.html.

[25] Daniel O'Brien, et al., *A Case Study of the Impact of Bioenergy Development Upon Crop Production, Livestock Feeding, and Water Resources Usage in Kansas*. 2008 Annual Meeting 6432, American Agricultural Economics Association, Orlando FL (July 2008), http://ageconsearch.umn.edu/bitstream/6432/2/467207.pdf.

[26] D. Keeney & M. Muller, *Water Use by Ethanol Plants: Potential Challenges* (2006). Institute for Agriculture and Trade Policy, Minneapolis MN (October 2006), http://www.agobservatory.org/library.cfm?refid=89449.

Andy Aden, *Water Usage for Current and Future Ethanol Production*, September/October 2007, SOUTHWEST HYDROL, National Renewable Energy Laboratory, http://www.wepapers.com/Papers/50093/Water_ Usage_for_ Current_and_ Future__Ethanol_Production.

facility that produces 100 million gallons per year (mgy) would use between 300-700 million gallons of water per year just in ethanol production at the plant. Most state-of-the-art biorefineries that use corn as the feedstock report an average water use of 4.2 gallons per gallon of ethanol produced (this is the 2005 average, later Keeney and Muller use 4.0 gallons as the multiplier, Aden uses 4.2 gallons).[27] Using the 4.0 gallon figure, a 100 mgy biorefinery will use an estimated 400 million gallons of water, or approximately the same amount of water a town with a population of about 6,100 would use on an annual basis (using the estimated national average of 180 gallons per capita per day figure from the USGS).[28]

However, we cannot forget the water it takes to actually grow the corn. As mentioned above, in northwest Kansas and Nebraska, corn requires about 2,150 gallons of water to produce a bushel of corn (that is in addition to natural rainfall). Since each bushel of corn can be converted into about 2.8 gallons of ethanol,[29] approximately 750 to 800 gallons of water is required to produce each gallon of ethanol.[30] Thus, Kansas/Nebraska region, the water needed to grow a bushel of corn requires about 200 times more water than the 4.0 gallons a biorefinery would use to produce a gallon of ethanol.

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[27] *Id*. (both Keeney & Muller and Aden).

S. Phillips, et al., *Thermochemical Ethanol via Indirect Gasification and Mixed Alcohol Synthesis of Lignocellulosic Biomass.* Technical Report NREL/TP-510-41168 (April 2007), *available at* http://www.nrel.gov/docs/fy07osti/41168.pdf .

[28] Susan S. Hutson, *et al.*, *Estimated Use of Water in the United States in 2000* (2004), U.S. GEOL SURV CIRC #1268, *available at* http://pubs.usgs.gov/circ/2004/circ1268/pdf/circular1268.pdf. Also see National Research Council, *supra*, note 24.

[29] R.J. Bothast & M. A. Schlicher. *Biotechnological processes for conversion of corn into ethanol.* 67(1) APPL MICROBIOL BIOTECHNOL 67 (2004), doi: 10.1007/s00253-004-1819-8.

Also see O'Brein, *supra*, note 25.

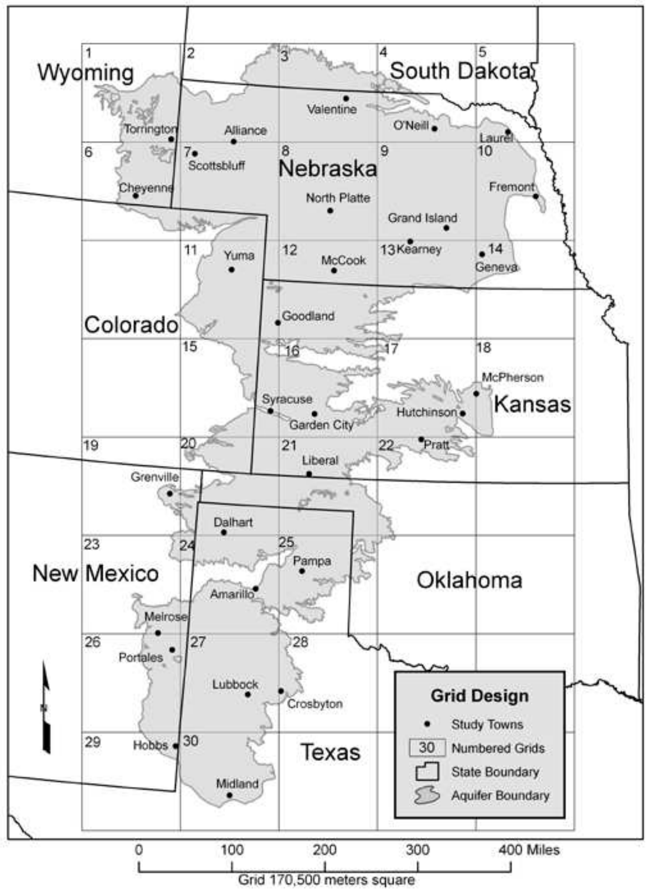
[30] See National Research Council, *supra*, note 24.

IV. Survey Design

In an attempt to select communities in the most *objective* manner possible, the study area, consisting of 174,000 square miles, was divided into identically-sized grids by utilizing the "fishnet" function in ArcGIS. To ensure coverage of the entire aquifer, it was necessary to create five columns and eight rows of grids, with a grid size value (width and height) of 170,500 square meters (see Figure 2 below). This technique follows along with several U. S. Geological Survey studies that utilize a grid system to subdivide the Ogallala aquifer into manageable areas for further study (see Luckey, et al.[31] and Qi, et al.[32]). Once the grids were established, the largest municipality by population with a municipal water system was chosen within each of the 30 grids overlying the aquifer. Using population size as a determinant generates perhaps the most heterogeneity across communities simply because most grids are sparsely populated. Hence, our city sample consists of not only very small communities in the hundreds (for instance, Laurel, Nebraska, with a population of 986), but also communities in the hundreds-of-thousands (such as Lubbock, Texas, with a population of about 215,000).

[31] Luckey, et al., *Digital Simulation of Ground-Water flow in the High Plains Aquifer in Parts of Colorado, Kansas, Nebraska, New Mexico, Oklahoma, South Dakota, Texas, and Wyoming* (1986), Regional Aquifer-System Analysis, PROF PAPER 1400-D, *available at* http://pubs.er.usgs.gov/djvu/PP/pp_1400_b.djvu.

[32] Qi, et al., *Classification of Irrigated Land Using Satellite Imagery, the High Plains Aquifer, Nominal Date 1992* (2002). National Water-Quality Assessment Program GEOL SURV WAT-RES INV REP #02-4236, http://pubs.usgs.gov/wri/wrir02-4236/pdf/wri02-4236.pdf.



The telephone survey portion of the project was conducted by the Earl Survey Research Laboratory (ESRL) at Texas Tech University during the fall of 2009 and the spring of 2010. ESRL has a multi-station phone bank that utilizes the latest in interviewing software, and employs only personnel that are professionally trained to conduct the survey (these were not automated surveys). To ensure a random sample, a random digit dialing (RDD) sampling method was used, which includes listed and unlisted phone numbers.[33] The survey consisted of 32

[33] Earl Survey Research Laboratory, Telephone Surveys (2010), http://www.orgs.ttu.edu/earlsurveyresearchlab/telephonesurveys.php.

questions, including general demographic questions, questions that dealt with attitudes toward water conservation policy, and questions that attempted to "tease out" any tension between agriculture, the ethanol industry and municipalities.

Previous surveys dealing with attitudes regarding water consumption and conservation have utilized the Likert scale for data gathering and analysis (see Gregory and Leo[34] and Story and Forsyth[35]). This is a rating scale that measures the strength of a respondent's opinion toward a question or statement using anywhere from four up to ten potential choices.[36] The empirical survey methodology for this study was based on Pumphrey, et al.[37] A 4-point scale that includes the responses 'strongly agree,' 'agree,' 'disagree,' and 'strongly disagree' was used in the seed study and is utilized in this study.

The original intent was to survey 100 respondents in each of the 30 municipalities chosen, resulting in 3,000 observations. Grenville, New Mexico (the largest municipality in Grid 19) with a population of 25 was considered entirely too small to meet the originally set 100 respondent per town requirement.[38] To adhere to the original design, Grenville, NM was replaced with Yuma, Colorado (Grid 11). Yuma was chosen because it is located in Colorado, as the original selection process did not result in any Colorado communities being chosen. Yuma County is also one of the leading corn producing counties in Colorado and has one operational ethanol plant making it particularly interesting to include in the survey.[39] In addition, Crosbyton,

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[34] Gary D. Gregory & Michael Di Leo, *Repeated Behavior and Environmental Psychology: The Role of Personal Involvement and Habit Formation in Explaining Water Consumption*, 33(6) J APPL SOC PSYCHOL 1261, 1296 (2003), http://onlinelibrary.wiley.com/doi/10.1111/j.1559-1816.2003.tb01949.x/pdf.

[35] Paul A. Story & Donelson R. Forsyth, *Watershed conservation and preservation: Environmental engagement as helping behavior*, 28(4) J ENVIRON PSYCHOL 305, 317 (2008), doi: 10.1016/j.jenvp.2008.02.005.

[36] JUDITH BELL, DOING YOUR RESEARCH PROJECT (1999).

[37] See Pumphrey, et al., *supra*, note 3.

[38] United States Census Bureau (2010), American FactFinder, http://factfinder.census.gov/home/saff/main .html?_lang=en. Fact sheet for community, type community name and choose state from drop-down menu.

[39] Yuma County Economic Development Corporation, Northeastern Colorado Economic Developers, Yuma County, Colorado, http://www.northeasterncolorado.com/htm/counties/yuma.php.

Texas (Grid 28) did not have a pool of available (and randomly sampled) phone numbers that was large enough to meet the 100 respondent requirement, as ESRL ended up with only 13 completed interviews; hence, this community was altogether dropped from our sample. Due to costs, it was not replaced with another community. To this end, the total number of communities interviewed was 29.

V. Results and Policy Implications

The first table below lists the results from the questions of interest regarding municipal water policy, Table 2 lists results from a more refined set of pricing questions, while Tables 3 and 4 list results from the questions regarding the respondent's attitudes toward the agricultural and ethanol communities.

But, before we attempt to comment on the tables, it is important to show the reader there is indeed a vested interest in water conservation policy for the individuals we interviewed. Two questions we ask to try to tease out this information are:

(i) "Do you think you will be living in [this state] 20 years from now?" and

(ii) "How important should water conservation be to [your city's] local government?"

The intention of the former question is to determine whether the respondent will be in the state for a long enough period of time to be significantly impacted by ground water depletion and subsequent changes in water policy; 71% replied yes to this statement, and just over 24% responded no; the remainder either refused to answer or did not know whether they will be living in their state more than 20 years. (As with the remainder of the questions, any deviation from a 100% response implies either a ‘do not know’ response or a refusal to answer the question. The responses just mentioned totaled 95% of possible respondents, indicating that about 5%

responded 'do not know' or simply refused to answer the question.) In other words, about 71% of those surveyed should have a vested interest in state resources and policy.

The intention of the second question is to reveal whether the respondent is concerned about their community's water strategy. The response choices for this question are on a 5-point scale with 1 being not at all important and 5 being very important. Only 3.4% responded with a 1 or 2 on this scale, implying that just over 3% think that water conservation should not be important to their local government; furthermore, only 8.5% responded with a degree of 3 indicating indifference to the importance of water conservation. However, 88.1% responded with at least a 4 on this scale, with almost 72% responding with a level 5. Therefore, over 88% indicate that water conservation should be an important issue concerning their local government, and about three-quarters think this issue is a very important one. Hence, the responses to these two questions seem to indicate that the population we surveyed does indeed have a vested interest in municipal water conservation at least in their particular communities. We will therefore make the reasonable assumption that the responses we receive are 'thoughtful' responses.

As mentioned above, the original survey was oriented around a four-point, Likert scale of strongly agree, agree, disagree, and strongly disagree. For a more parsimonious exposition, in Table 1 we combine strongly agree and strongly disagree responses into either agree or disagree respectively. The numbers in the Agree and Disagree columns represent the number of communities whereby the statistically significant majority of constituents responded agree or disagree (significant at 90%). The indifferent responses are characterized by statistical insignificance between agree and disagree for each community. Using the word "indifferent" may confuse the reader. However, technically what is occurring when there is no statistically significant majority answering agree or disagree is a split result—effectively indicating that the population is split on the issue and the ultimate policy decision then lies in the hands of the official. We believe, then, based on the available survey data that the official will view the public opinion as split (or indifferent) and pursue the policy that he/she believes is appropriate. Therefore, response percentages within the margin of error imply indifference to that question. The right-hand column is probably the most controversial as it lists the overall inference *we* draw from the results in the other columns about prevailing attitudes across this region. This inference will be based upon the numbers (the total number of communities) in the Agree, Disagree, or Indifferent columns, relative to the other two outcomes.

This first set of questions represent an attempt at gauging what constituents in these communities think about a broad set of regulatory and pricing policies. The reader will notice especially that the pricing questions are open-ended with regard to the actual size of the price change. We modify these questions later to draw a more precise inference from the price questions.

Question set 1

1. Mandatory water restrictions enforced by your local government, such as limiting car washing, lawn watering, plant and garden watering, and so on, are a good way to help save water during periods of drought.

2. Increasing the price of water during periods of drought would be a good way to help save water during these periods.

3. Mandatory water restrictions such as those just mentioned would be ignored by many in your community.

4. Mandatory water restrictions such as those just mentioned would be 'strictly' enforced by your community's officials such as the police department, water department, and such.

5. Increasing the price of water when there is 'not' a drought would be a good way to help save water for the future.

6. Mandatory water restrictions are a good way to help save water for the future even if there is no drought.

Table 1: Totals for questions 1 – 6

Question #	Total n	Mean n	# Agree	# Disagree	# Indifferent	Inference
1	2935	101.2	29	0	0	Agree
2	2920	100.6	1	5	23	Indifferent
3	2850	98.2	21	1	7	Agree
4	2814	97.0	24	0	5	Agree
5	2911	100.3	0	28	1	Disagree
6	2906	100.2	27	0	2	Agree

The letter 'n' refers to the number of respondents that answered the particular question. # Agree and # Disagree refers to the number of communities whereby a statistically significant majority of those surveyed either agreed or disagreed with the question, respectively. # Indifferent refers to the number of communities in the study whereby there was no statistically significant majority of agree or disagree responses; in other words, these communities were effectively 'split' in their response to the question.

The numbers displayed in Table 1 tell a fairly unambiguous story. Imposing mandatory restrictions during a drought is unanimously acceptable by a majority of citizens in all of the 29 communities interviewed. Furthermore, increasing prices during a drought would not be rejected outright in 23 of the 29 communities and is acceptable in one other; however, increasing rates during a drought in the Nebraska communities of Alliance and North Platte, Goodland Kansas, Melrose, New Mexico, or the Texas community of Pampa, would not be supported by the majority of constituents. What these communities have in common is not at all clear given that there are hundreds of miles between them; future research should investigate possible similarities that could have generated such an outcome.

Nevertheless, while there is unanimous approval with implementing water restrictions, questions 3 and 4 indicate this would be a costly approach. The results from question 3 tell us that the majority of residents of 21 of the 29 communities do not trust their neighbors to abide by such policies and those in 7 other communities are split on this opinion. The only respondents that seem to actually trust their neighbors to abide by such regulatory policy are those in Cheyenne, WY. Again, and as with many of the outcomes outlined in the remainder of the manuscript, the characteristics of exactly why those in Cheyenne respond this way when no other community does, is an interesting area for future research. If there actually is circumvention of regulatory policies, this will result in substantial oversight and enforcement. On the bright side, the responses to question 4 indicate that respondents in 24 communities agree with the ability of their prescribed agencies to enforce said policies, while the other 5 are split on this issue.

Questions 5 and 6 are meant to capture opinions of pricing and regulatory policy on a more permanent schedule by essentially re-asking questions 1 and 2, but with the assumption that there is no drought and that any water conservation policy would be applied on a longer-term basis. We find that there is almost unanimous disagreement with increasing prices in these communities and also near unanimous agreement for implementing some permanent level of regulatory policy. And while the message from the responses of question 5 is clear enough, the message from question 6 seems to us to be more complicated.

We interpret the response to question 6 as indicative of respondents observing significant water waste already occurring in their community. Forms of waste may be lawn sprinkler systems operating while it is raining, or letting hoses run while washing cars, etc. We believe that an agree response to question 6 supports the idea that there is some level of regulatory measure, such as a requirement that if one washes their car they have a shut off head attachment connected to the hose; or perhaps creating legislation that one is forbidden from watering their lawn during periods of sufficient rainfall.

Using just the responses from the 6 questions outlined in Table 1, a community's water policy model in the research area would be one whereby during droughts, both regulatory and pricing measures are feasible options in most communities, but that substantial enforcement of the regulatory-side is required. Furthermore, community officials should look for areas of water waste that are likely occurring in their community and impose a permanent measure that would curb the likelihood that the waste continues.

There is a one problem with this analysis so far, however, and that is with regard to the pricing questions, 2 and 5. The problems are (1) there was no upper bound on the price increase, i.e., they were simply open-ended increases, and (2) there is no indicator of how much prices should rise in order to have a substantial effect on water consumption. To this end, we asked a few more questions much later in the survey to try to tease out what sort of price increase would be acceptable and what effect it would have. These questions are:

7. I personally would use less water if I were charged more for it.

8. How much of an increase in the price of water would it take for you to reduce the amount of water your household uses: 25% more, 50% more, 75% more, 100% increase, or I would not reduce my consumption regardless of the increase in price.

9. How much of an increase in the price of water would be too much to ask for: 25% more, 50% more, 75% more, 100% increase, greater than a 100% increase.

As the reader will notice, levels were actually affixed from 25% through 100% increase in price, and while the levels themselves are somewhat arbitrary, we wanted to make the changes substantial enough to encourage meaningful responses.

As with many communities across the U.S., the water charges of a typical household are likely to be the lowest of their household bills. Electricity bills typically have amounts 5 times that of the water bill;[40] even monthly cable television[41] and cell phone charges[42] are 3 times larger than a household's water charges, on average.

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[40] United States Energy Information Administration, http://eia.doe.gov/electricity/esr/table5.html, estimates average monthly electricity bill at $103.67 for 2008.

[41] MultiChannel News estimates the average cable television bill is $71 per month, http://www.multichannel.com/article/196364-Study_Average_Cable_TV_Bill_Is_71_Per_Month.php

[42] J.D. Power estimates the average household cell phone bill is $73 per month, http://www.wirefly.com/learn/wireless_news/jd-power-analyzes-average-cell-phone-bill/

The United States Geological Survey (USGS) estimates that the typical person will use anywhere between 80 to 100 gallons of water each day. Using 90 gallons per capita per day average, a typical household (of 4) would use approximately 10,800 gallons per month (overall consumption including lawn irrigation, car washing, etc.).[43] In Dalhart, Texas, there is a $7 base charge per month, and a $1.82 per 1,000 gallon charge after the first 2,000 gallons; this implies an average monthly bill of $23.06. In Garden City, Kansas, a typical consumer's monthly bill would be about $20.70. Therefore, while the percentage increases seem large, the actual dollar amount increases are much smaller. A 25% increase in these towns would result in a monthly bill increase of only between $5 and $6, assuming no drop in use.

Table 2: Totals for questions 7 - 9

Question #	Total n	Mean n	# Agree	# Disagree	# Indifferent		Inference
7	2910	100.3	16	0	13		Agree/Indiff
			25% Price Increase	50% Price Increase	75% Price Increase	100% Price Increase	No Demand Reduction
8	2784	96.0	39.3	25.7	4.3	4.3	26.2
							Greater than 100%
9	2857	98.5	40.7	33.9	14.2	6.9	4.1

The letter ‘n’ refers to the number of respondents that answered the particular question. For question 7, # Agree and # Disagree refers to the number of communities whereby a statistically significant majority of those surveyed either agreed or disagreed with the question, respectively. # Indifferent refers to the number of communities in the study whereby there was no statistically significant majority of agree or disagree responses; in other words, these communities were effectively ‘split’ in their response to the question. For questions 8 and 9, the numbers underneath the price increase percentage headings are the actual percentages of responses for that category.

Table 2 lists the responses from questions 7 - 9. The row containing the responses for question 7 can be interpreted the same way as those in Table 1. Interpretation of the rows containing responses to questions 8 and 9 is as follows. The percentage price increases are as

[43] United States Geological Survey, Water Science for Schools, http://ga.water.usgs.gov/edu/qahome.html.

described in the questions outlined above, but the numbers below each price increase represent the mean percentage responses across all communities. For instance, on average, 39.3% of respondents across all communities would reduce their water consumption with a 25% increase in the price of water, and 40.7% of constituents think that a 25% increase in the price of water is too much to ask for. So, if usage is reduced as prices increase, then the monthly bill increase would total less than the $5-$6 mentioned above.

The results of question 7 in Table 2 tell us that in general, a statistically significant majority of constituents in 16 communities would reduce their water consumption when faced with a price increase, while only about one-half of those in the remaining communities would reduce their consumption. But exactly what level of price increase would be effective? According to the results for question 8, a 25% increase would affect about 39% of the constituents; a 50% increase would affect approximately another 26% of the population in these communities, and another 4% would be affected by each of the 75% and 100% increase levels. There is roughly 26% of the population that claim that they would not reduce their consumption regardless of the price increase. People in this category likely reside in one of three groups. The first group contains those that are already using the most basic amount of water for their needs and simply cannot reduce consumption any further. The second group likely consists of people with incomes large enough to absorb even a 100% increase in their water bill; and the third group could be those that are simply protesting against a price increase and therefore respond harshly to such a question. More intriguingly, however, are the responses to question 8 combined with inference drawn from the responses to question 9.

For question 9, roughly 41% of respondents believe that a 25% increase in the price of their water is too much to ask for. But this also implies that roughly 59% of respondents are “okay” with a 25% increase in prices. Combined with the inference drawn from the results in Table 1, we can now outline a general policy model for communities on the High Plains that use the Ogallala as a municipal water source.

The model is such: during periods of drought, the appropriate policy response would remain a regulatory response which would also be quite expensive to implement. However, the citizens of these communities also seem to understand that a temporary price increase would be helpful with increasing conservation during these periods. As a longer-term strategy, community officials need to be aware of obvious waste and implement long-term regulation to address such waste. In addition, our data show that even though citizens of these communities disagree with an arbitrary increase in prices to save water for the future, an increase of 25% would not be prohibitively large and would have a conservatory effect on about 40% of the population of these communities.

VI. Reflections on the Agricultural Sector

Since this area of the country is so highly dependent on agriculture, it certainly behooves us to investigate the respondent's attitudes toward those that many believe are actually causing the groundwater shortages— the agriculture and ethanol sectors. The analyses above certainly tells us that constituents are aware of their resource problem, and that potentially, both a long and short-term hybrid strategy of pricing and regulatory measures would be a more efficient strategy than that currently being implemented over the Ogallala. However, we also saw that the effects of this strategy will be limited to at most 40% of the respondents reducing their water consumption in the short-run, with an unpredictable effect for a permanently-implemented regulatory strategy. With limited results such as these, yet such a critical situation that exists on the High Plains with regard to water availability, it may be the case that constituents believe the onus of water conservation actually stands with the farmer and ethanol plants, and not with themselves (the municipal consumer). If this is indeed the case, it represents perhaps one of the most interesting societal conflicts between two inter-dependent economic groups in the country.

If respondents believe that the burden of conservation lies mostly with the agricultural and ethanol sectors, this result would be very interesting. Nearly every one of these communities depend highly on these two industries for employment, and hence, income. Table 3 lists the descriptive results for two questions that try to measure area dependence on these sectors. Question 10 asks "How important do you think the agricultural industry is to your city?" and question 11 asks "How important do you think the ethanol industry is to your city?" What we find is that about 92% of the survey respondents identified the agricultural industry as important, and 81% deemed it very important; nearly one-quarter of respondents indicated that they believe the ethanol sector is very important, with an additional 17% seeing it as important.

Table 3: The Importance of the Agricultural and Ethanol Industries

Question #	Total n	Mean n Per city	Not Important…				…Very Important
10	2966	102	1.24	1.44	5.37	10.93	81.02
11	2816	97	14.41	17.03	29.11	16.79	22.52

The letter 'n' refers to the number of respondents that answered the particular question. The numbers underneath the Not Important to Very Important scale are the actual percentages of responses for that category.

Given that the dependency on these sectors is great, a priori, one would think that a municipal constituent's attitude toward the industry's responsibility for water conservation might be muted. We asked 4 simple questions that try to measure this attitude toward the agricultural and ethanol sectors:

12: Farmers should pay for all of the water they use.

13: Ethanol producing companies should pay for all of the water they use.

14: Every year, farmers should be limited to a set amount of water they can use for irrigation, and they should have to pay for any amount over that limit.

15: Farmers should be fined for wasting water.

Table 4 lists these results in the same fashion as Table 1. What is interesting here is that even though these communities are highly dependent on these sectors, they also firmly believe that they should shoulder their fair share of the burden of water conservation. Indeed, nearly one-third of the 29 communities believe that farmers should pay for all of the water they use for irrigation, while just short of two-thirds are indifferent to such a proposal. All of the communities also believe that ethanol producers should not be subsidized for any of the water they use, hence should pay for all of it. And with regard to the farming outcome, when we rephrase the question to allow for a limited amount of irrigation water free of charge and the farmer paying for any amount over the allotment, two-thirds give unanimous consent! This result essentially holds for the idea of fining farmers for wasting water as well whereby 26 of the 29 communities agree with this concept, and the other 3 communities are indifferent to such a proposal.

Table 4: Totals for questions 12 — 16

Question #	Total n	Mean n	# Agree	# Disagree	# Indifferent	Inference
12	2755	95	9	2	18	Indifferent
13	2812	97	29	0	0	Agree
14	2810	97	19	0	10	Agree
15	2873	99	26	0	3	Agree

The letter 'n' refers to the number of respondents that answered the particular question. # Agree and # Disagree refers to the number of communities whereby a statistically significant majority of those surveyed either agreed or disagreed with the question, respectively. # Indifferent refers to the number of communities in the study whereby there was no statistically significant majority of agree or disagree responses; in other words, these communities were effectively 'split' in their response to the question.

There does seem to be strong support for the agricultural and ethanol sectors bearing much of the burden of water conservation in this area of the country, regardless of the fact this area is highly dependent on these industries for their livelihoods. A reasonable explanation, but only arguably correct, is that constituents are acutely aware of not only the depletion of the aquifer, but they are also aware that farmers are the main cause. They are also probably aware of the fact that much of their industry is heavily subsidized by the taxpayer, not just in a pecuniary sense, but also by the fact that the vast majority of farmers in these areas do not pay for their irrigation water—only the energy to pump it. The subsidy comes in the form of a transfer of wealth from the municipal constituent to the farmer. As community well fields are depleted because of surrounding irrigation activity, new well fields must be found, drilled, and piped—this is at taxpayers' expense. Furthermore, as well fields are depleted, communities are finding it more difficult to find new fields that are viable for long-term extraction due to irrigation practices; this also raises the cost of water for the municipal resident. As the water table drops, less water is available and the total dissolved solids and contaminants will be in higher concentration causing the quality to decline for the farmer, the biorefinery and the municipality. These constituents, then, must be making a subconscious (or conscious) calculation that the losses from water scarcity must exceed the potential cost of constraining the agricultural and biofuels sectors and the resulting potential reductions in income.

VII. Conclusion

In this paper we have demonstrated the critical importance of the Ogallala for municipalities in the region. On the one hand, residents of this region desire economic growth and prosperity, which are inexorably tied to agriculture. However, as the agriculture and ethanol industries in the region grow, water resources will inevitably grow more costly as wells for this scarce resource must be increasingly re-drilled, and the water filtered and piped from longer distances. It is not a matter of if these changes occur, but when.

As evidenced by our surveys, the residents of this region are aware of this inevitability, and in large part agree on several principles. They agree that restricting water use is a useful way to conserve water, whether during periods of drought or permanently. While there is resistance to a vague notion of increasing water prices for conservation, most residents would be willing to accept modest price increases for the purposes of conservation, accepting a small price today in order to forestall significant expenses in the future.

Also, while residents clearly acknowledge the importance of the agricultural and ethanol industries in their region, there is less resistance than might be anticipated in making these industries pay “their fair share” for the water they use. At a minimum, there is strong agreement that farmers, like municipal residents, should not waste this precious resource.

Even so, there are several communities which buck the prevailing trends. Future research should focus on identifying the determinants of these attitudes. Perhaps, even though located in a semi-arid region, these cities have escaped the grasp of a major drought in the recent past, and are feeling complacent about water use. Or, perhaps these areas have been hard hit by recession, and are willing to risk a future loss in exchange for a quicker economic recovery in the present. Whatever the reasons, changes cannot be made without the political will, which in turn depends critically on societal attitudes in this region.