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Building a *Simple* General Model of Municipal Water Conservation Policy for Communities Overlying the Ogallala Aquifer

ABSTRACT

On the United States' largest aquifer—part of the nation's Great Plains region—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 must be developed to encourage conservation of this resource that are efficient, effective, and 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

The current regulatory policy governing water consumption in the United States is cumbersome. Common sense would indicate that facets of regulatory policy, such as limits on water usage that affect lawn watering or car washing, as well as fines for over-use or waste, are costly to enforce. They distract police and water department officials from more important duties and add to the workload of a community's court system. Regulatory policy can be easily circumvented—e.g., someone with a privacy fence may water their grass before the prescribed time of day. Also, a regulation does not encourage conservation from those unaffected by it—e.g., someone who does not have a car is not affected by a car-washing restriction.

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On the other hand, a price-rationing approach that involves simply increasing the price of water to reduce usage is far less costly to enforce. 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 will arguably become a conscious factor in one's financial welfare.

The problem is 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 voter discontent may result. In essence, it could be suggested 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 would be deemed less so. However, when combined with current regulatory policy, a comprehensive strategy that includes price rationing by municipalities in this area of the United States would be a more effective prescription for conserving water than the current policy.

This study started as a result of a smaller study—a phone interview investigation of constituent attitudes toward water pricing and regulatory measures in several urban and rural West Texas municipalities.¹ The results of the smaller study supported the idea that the public would not wholly reject the need for a pricing mechanism to enhance water conservation when needed.² Both the smaller study and the current study focus on communities that overlie the Ogallala aquifer in the High Plains region of the United States. This study builds upon the smaller one, with a few twists.

The current study, funded by the National Science Foundation, Human and Social Dynamics Competition,³ tries to determine the most acceptable conservation strategy, and covers a much larger area than the

1. 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 *ECOLOGICAL ECON.* 1–12 (2008).

2. *Id.* at 10.

3. This is a three and one-half year project with a completion date of February 2012, funded by National Science Foundation Human and Social Dynamics Competition, 9/1/2008–2/29/2012, BCS-0826778, amount \$757,528. *HSD Changing Social Attitudes Toward Water Scarcity: Ethanol Production and Increasing Groundwater Depletion of the Ogallala Aquifer*,

previous study with far more interviews conducted. The seed study investigated only six communities in an area of approximately 4,700 square miles in the northwestern portion of Texas. The current study covers parts of eight 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.

This study also attempts to ascertain constituent attitudes toward the agricultural and ethanol industries. 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.⁴ Therefore, though both studies formulated questions to evaluate and determine constituent attitudes toward pricing and regulatory measures, the current research added questions to try to determine attitudes toward the agriculture and ethanol industries in this part of the country.

Interestingly, despite increasing the geographic heterogeneity of the survey group, a surprising homogeneity in responses was the norm. This study found that during periods of drought, the most popular form of municipal water conservation is indeed a regulatory response; however, a near unanimous indifference exists toward temporary price increases during these periods. In fact, in only five of the 29 communities did 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 respondents indicated that they would accept a 25% increase. Our results suggest that 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 that members of the community have observed water being wasted and have determined that the permanent implementation of a regulatory measure is 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 see the need for a permanent regulatory measure that prohibits the use

NAT'L SCI. FOUND., available at <http://www.nsf.gov/awardsearch/showAward.do?AwardNumber=0826778&version=noscript> (Sept. 30, 2010).

4. *The High Plains Aquifer Hydrogeologic Characterization, Mapping, Modeling and Monitoring Act: Hearing on S. 212 Before the Subcomm. on Water and Power of the S. Comm. on Energy and Natural Resources*, 108th Cong. (2003) [hereinafter *Hearings*] (testimony of Peter Scholle & M. Lee Allison, High Plains Aquifer Coalition), available at <http://www.kgs.ku.edu/Hydro/HPAC/Testimony/scholle2003.html> (last visited Feb. 19, 2012).

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 people's views on the agricultural and ethanol sectors, our results indicate that about 92% of 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 nine 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 two 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.

These findings suggest that communities dependent on the Ogallala aquifer for 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. This would result in a substantial reduction in quantity demanded within these communities. Even though constituents are largely aware that they are inherently tied to agriculture-related industries, they probably also believe that farmers are not charged sufficiently for their irrigation needs and should probably play a larger role in water conservation.

Part II of this article describes the subject area of this study. Part III of this article outlines corn and ethanol production in the High Plains area. Part IV of this article describes the survey design in detail. Part V of this article describes the results of the survey. Part VI of this article outlines the impact the results of this survey may have on the agricultural sector.

II. THE HIGH PLAINS AND THE OGALLALA AQUIFER

The study area overlies the Ogallala aquifer, which covers 174,000 square miles in parts of Colorado, Kansas, Nebraska, New Mexico, Oklahoma, South Dakota, Texas, and Wyoming, and on which 2.3 million people reside.⁵ (See Figure 1, below, in Part IV). 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

5. See *Hearings*, *supra* note 4.

29 communities is that some portion of the municipal drinking water supply originates as groundwater from the Ogallala.⁶

The Ogallala study area is characterized by a high, fairly flat, treeless plain with grasslands, prairie, farmland, and 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.⁷

The Ogallala aquifer, often referred to as the High Plains aquifer, is the largest water-bearing underground formation in the United States.⁸ It has long been the principal aquifer in the region, as agriculture, municipalities, and industry all rely heavily upon the groundwater for irrigation, livestock production, and other domestic and industrial uses. Recently, the ethanol industry has begun to increase production in the Great Plains,⁹ which will put even more stress on the aquifer. As of June 2010, the Renewable Fuels Association reported 33 operational ethanol plants located in the study area, with a majority of the plants concentrated in Nebraska and Kansas, along with three plants under construction as of December 2010.¹⁰

More groundwater is pumped from the Ogallala aquifer than is pumped from any other aquifer in the United States, as it supplies the region with almost 30% of all groundwater that is used in the entire United States for irrigation.¹¹ While irrigation for agriculture accounts for almost 95% of the groundwater pumped from the Ogallala, just over 80% of the population in this area depends on the Ogallala for everyday

6. GUTENTAG ET AL, U.S. GEOLOGICAL SURVEY GEOHYDROLOGY OF THE HIGH PLAINS AQUIFER IN PARTS OF COLORADO, KANSAS, NEBRASKA, NEW MEXICO, OKLAHOMA, SOUTH DAKOTA, TEXAS, AND WYOMING, PROF'L. PAPER 1400-B 2 (1984), available at <http://pubs.usgs.gov/pp/1400b/report.pdf>. See also KEVIN F. DENNEHY, U.S. GEOLOGICAL SURVEY, HIGH PLAINS REGIONAL GROUND-WATER STUDY (2000), available at <http://co.water.usgs.gov/nawqa/hpgw/factsheets/DENNEHYFS1.html> (last visited Mar. 4, 2012).

7. U.S. GEOLOGICAL SURVEY, HIGH PLAINS WATER-LEVEL MONITORING STUDY (2010), available at <http://ne.water.usgs.gov/ogw/hpwlms/physsett.html>.

8. Jacque Emel & Rebecca Roberts, *Institutional Form and Its Effect on Environmental Change: The Case of Groundwater in the Southern High Plains*, 85 ANNALS ASS'N AM. GEOGRAPHERS 664, 665 (1995), available at <http://links.jstor.org/sici?sici=0004-5608%28199512%2985%3A4%3C664%3AIFAIEO%3E2.0.CO%3B2-P> (last visited Mar. 4, 2012).

9. Sparks Companies & Kansas State University, *Teaching Note: The US Ethanol Industry with Comments on the Great Plains*, AGRICULTURAL MARKETING RESOURCE CENTER, available at <http://www.agmanager.info/agribus/energy/Teaching%20Note%20The%20US%20Ethanol%20Industry.pdf>.

10. *Biorefinery Locations*, RENEWABLE FUELS ASS'N [hereinafter RFA], <http://www.ethanolrfa.org/bio-refinery-locations> (last updated Jan. 10, 2012).

11. GUTENTAG ET AL, *supra* note 6, at 7; see also *Hearings*, *supra* note 4.

water needs.¹² Water levels started to decline as soon as large-scale pumping began in the 1930s and 1940s—a period commonly referred to as “predevelopment,” although some experts consider predevelopment to extend into the 1950s and 1960s in certain regions.¹³ Estimated annual recharge of the Ogallala ranges from a meager 0.02 inch annually in the southwest portion to six inches per year in the northeast region of the aquifer.¹⁴ In most areas overlying the aquifer, withdrawals have significantly exceeded natural recharge, thus the majority of the aquifer is considered nonrenewable.¹⁵ In essence, the Ogallala aquifer is being “mined,” meaning water is being withdrawn at a rate much greater than recharge. From predevelopment to 1980, water levels dropped as much as 100 feet or more in parts of southwestern Kansas, Oklahoma, and Texas.¹⁶ One commentator 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.”¹⁷ From predevelopment to 2007, approximately 13% of the aquifer had at least a 25% decline in saturated thickness.¹⁸

III. CORN AND ETHANOL PRODUCTION IN THE HIGH PLAINS AREA

The Energy Policy Act of 2005¹⁹ mandated a Renewable Fuels Standard for U.S. fuel production and was amended by the Energy Independence and Security Act of 2007.²⁰ It called for an increase in the annual amount of ethanol that is to be mixed with gasoline (and sold in the United States) from four billion gallons in 2006, to 7.5 billion gallons by 2012.²¹ Historically, Congress has approved fairly substantial subsidies to

12. See *Hearings*, *supra* note 4; see also DENNEHY, *supra* note 6.

13. LUCKEY ET AL., U.S. GEOLOGICAL SURVEY, 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, HYDRAULIC INVESTIGATIONS (1981), available at <http://pubs.usgs.gov/ha/652/plate-1.pdf>.

14. See GUTENTAG ET AL., *supra* note 6, at 31.

15. See GUTENTAG ET AL., *supra* note 6, at 45.

16. See *id.*

17. V.L. MCGUIRE, U.S. GEOLOGICAL SURVEY, WATER-LEVEL CHANGES IN THE HIGH PLAINS AQUIFER, PREDEVELOPMENT TO 2007, 2005–06, AND 2006–07 5 (2009), available at <http://pubs.usgs.gov/sir/2009/5019/pdf/sir2009-5019.pdf>.

18. *Id.* at 7.

19. Pub. L. No. 109-58 § 1501, 119 Stat. 594, 1067–76 (amending 42 U.S.C. § 7545).

20. Pub. L. No. 110-140 § 202, 121 Stat. 1492, 1521–28 (codified as amended at 42 U.S.C. § 7545).

21. BRENT D. YACOBUCCI & RANDY SCHNEPP, CRS REPORT FOR CONGRESS: SELECTED ISSUES RELATED TO AN EXPANSION OF THE RENEWABLE FUELS STANDARD (RFS) 3,4 (2007), available at <http://fpc.state.gov/documents/organization/98150.pdf>.

biofuel producers and blenders, thus ethanol production capacity has steadily increased since 2005.²² As of December 2010, Congress extended the tax incentives for ethanol production and use for one year.²³ Estimates back in 2007 were that U.S. ethanol production capacity would be in excess of 12 billion gallons, which is well above the 2012 standard.²⁴

The sole source of water for irrigation in most areas overlying the Ogallala aquifer is groundwater.²⁵ Precipitation during the growing season in most of the study area is not sufficient for substantial crop production and, therefore, irrigation is necessary.²⁶ As of 2007, 98% of biofuels production facilities (biorefineries) in the United States used corn as their main feedstock.²⁷ As of September 2010, all but one biorefinery in the study area used corn as their feedstock.²⁸ Corn production in the study area can take as much as double the amount of water as cotton, wheat, or sorghum.²⁹ In 2003, several commentators 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.³⁰ This translates into 5.4 trillion gallons of water needed just for ethanol production alone.

22. Gregory McKee, *Evaluating the Effect of State Ethanol Production Subsidies in the Upper Great Plains*, RENEWABLE ENERGY NEWSLETTER (AGRIC. MKTG. RES. CTR.) April 2010, available at http://www.agmrc.org/renewable_energy/ethanol/evaluating_the_effect_of_state_ethanol_production_subsidies_in_the_upper_great_plains.cfm (last visited Mar. 4, 2012). See also KEVIN C. DHUYVETTER ET AL., THE U.S. ETHANOL INDUSTRY: WHERE WILL IT BE LOCATED IN THE FUTURE? (AgMRC 2005), available at [http://www.agmanager.net/agribus/energy/Ethanol%20Industry\(AgMRC\)—11.25.05.pdf](http://www.agmanager.net/agribus/energy/Ethanol%20Industry(AgMRC)—11.25.05.pdf), at 2.

23. *Senate Passes Bill Extending Key Ethanol Tax Incentives*, RFA (Dec. 15, 2010), available at <http://www.ethanolrfa.org/news/entry/senate-passes-bill-extending-key-ethanol-tax-incentives>.

24. Paul Westcott, *U.S. Ethanol Expansion Driving Changes Throughout the Agricultural Sector*, AMBER WAVES, Sept. 2007, available at <http://www.ers.usda.gov/AmberWaves/September07/Features/Ethanol.htm> (last visited Mar. 4, 2012).

25. See GUTENTAG ET AL., *supra* note 6, at 40.

26. *Id.* at 45.

27. See YACOBUCCI, *supra* note 21, at 6.

28. See RFA, *supra* note 10.

29. NASS, U.S. DEP'T OF AGRIC., 2002 CENSUS OF AGRICULTURE: 2003 FARM AND RANCH IRRIGATION SURVEY (2002), available at http://www.agcensus.usda.gov/Publications/2002/FRIS/tables/fris03_28.pdf, at 90, 92, 93, 102. See also NAT'L RESEARCH COUNCIL COMM. ON WATER IMPLICATIONS OF BIOFUELS PRODUCTION IN THE U.S., WATER IMPLICATIONS OF BIOFUELS PRODUCTION IN THE UNITED STATES (2007), available at <http://www.nap.edu/catalog/12039.html>, at 20.

30. 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" presented at the American Agricultural Economics Association Annual Meeting, Orlando, FL, July 2008, available at <http://ageconsearch.umn.edu/bitstream/6432/2/467207.pdf>.

Other commentators estimated a 254% increase in the amount of water used in U.S. ethanol production in the 11-year period from 1998 through 2008, using data on biorefineries that were scheduled to start production by 2008.³¹ Studies have shown that biorefineries use anywhere between three and seven gallons of water per gallon of ethanol produced.³² That means the typical ethanol production facility that produces 100 million gallons per year (mgy) of ethanol 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.³³ Using a 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 U.S. Geological Survey (USGS).³⁴

All of this is concerning, even without considering the water it takes to actually grow the corn. In northwest Kansas and Nebraska, a bushel of corn requires about 2,100 gallons of irrigated water, aside from natural rainfall.³⁵ Each bushel of corn can be converted into about 2.8 gallons of ethanol,³⁶ and as mentioned above, approximately 750 to 800 gallons of water is required to produce each gallon of ethanol.³⁷ Thus, in northwest Kansas and Nebraska, the water needed to grow a bushel of corn requires about 200 times more water than the 4.0 gallons of water a biorefinery would use to produce a gallon of ethanol. These figures point to staggering conclusions. Policymakers, as well as the public, should be

31. D. KEENEY & M. MULLER, INST. FOR AGRIC. AND TRADE POLICY, *WATER USE BY ETHANOL PLANTS: POTENTIAL CHALLENGES* 5 (2006), available at http://www.iatp.org/files/258_2_89449.pdf.

32. Andy Aden, *Water Usage for Current and Future Ethanol Production*, SW. HYDROLOGY Sept.-Oct. 2007, at 22–23, available at http://www.wepapers.com/Papers/50093/Water_Usage_for_Current_and_Future_Ethanol_Production (last visited Mar. 4, 2012). See also KENNEY & MULLER, *supra* note 31, at 4.

33. See KEENEY & MULLER, *supra* note 31; Aden, *supra* note 32. (This is the 2005 average; for later periods, Keeney and Muller use 4.0 gallons as the multiplier, though Aden uses 4.2 gallons.) See also S. PHILLIPS ET AL., NATIONAL RENEWABLE ENERGY LABORATORY, *THERMOCHEMICAL ETHANOL VIA INDIRECT GASIFICATION AND MIXED ALCOHOL SYNTHESIS OF LIGNOCELLULOSIC BIOMASS*, (2007), available at <http://www.nrel.gov/docs/fy07osti/41168.pdf>.

34. See, e.g., SUSAN S. HUTSON ET AL., U.S. GEOLOGICAL SURVEY, *ESTIMATED USE OF WATER IN THE UNITED STATES IN 2000* (2004), available at <http://pubs.usgs.gov/circ/2004/circ1268/pdf/circular1268.pdf>. See also NAT'L RESEARCH COUNCIL *supra* note 29, at 46.

35. See NAT'L RESEARCH COUNCIL, *supra* note 29, at 51.

36. R.J. Bothast & M.A. Schlicher, *Biotechnological Processes for Conversion of Corn into Ethanol*, 67 *APPLIED MICROBIOLOGY & BIOTECHNOLOGY* 19, 19 (2005).

37. O'BRIEN ET AL., *supra* note 30, at 8.

aware (1) that irrigation for agriculture is depleting the water supply of the largest aquifer in Northern America; (2) that ethanol production will exacerbate this depletion; and (3) that this will result in less municipal water for communities in this region of the United States.

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.³⁸ 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.³⁹ This technique follows along with several USGS studies that utilize a grid system to subdivide the Ogallala aquifer into manageable areas for further study.⁴⁰ 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).

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 employed only personnel that are professionally trained to conduct the survey (these were not automated surveys). To ensure a random sample, a random digit dialing sampling method was used, which included listed and unlisted phone numbers.⁴¹ The survey consisted of 32 questions, including general demographic questions, questions that dealt with attitudes toward water conservation policy, and questions that attempted to “tease

38. Generated with ArcToolbox using the Create Fishnet function in ArcGIS 9.2 software.

39. See Figure 1, within Part IV.

40. See generally 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, U.S. GEOLOGICAL SURVEY, available at <http://pubs.usgs.gov/pp/1400d/report.pdf>.

41. *Telephone Surveys*, TEXAS TECH UNIV., Earl Survey Research Laboratory, <http://www.orgs.ttu.edu/earlsurveyresearchlab/telephonesurveys.php> (last visited Mar. 4, 2012).

out” any tension between agriculture, the ethanol industry, and municipalities.⁴²

The survey began with two preliminary questions.⁴³ The intention of the first preliminary question was to determine whether the respondent would 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. The intention of the second preliminary question was to reveal whether the respondent was concerned about their community’s water strategy.

The first set of questions represent an attempt at gauging what constituents in these communities think about a broad set of regulatory and pricing policies.⁴⁴ The initial pricing questions (2 and 5) were open-ended with regard to the actual size of the price change. We modified these questions later to draw a more precise inference from the price questions. Later in the survey, we addressed questions 2 and 5 because: (1) there was no upper bound on the price increase, i.e., they were simply open-ended increases, and (2) there was 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 to identify what sort of price increase would be acceptable and what effect it would have.⁴⁵ Notably, levels were actually affixed from a 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.

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. Therefore, we asked two other questions to measure area dependence on these sectors.⁴⁶

Finally, 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 four simple questions to measure this attitude toward the agricultural and ethanol sectors.⁴⁷

Previous surveys dealing with attitudes regarding water consumption and conservation have utilized the Likert scale for data gather-

42. The questions relevant to the results of the survey described in this article are provided in Appendix 1.

43. See *infra* Appendix 1.

44. See *infra* Question Set 1, Appendix 1.

45. See *infra* Question Set 2, Appendix 1.

46. See *infra* Question Set 3, Appendix 1.

47. See *infra* Question Set 4, Appendix 1.

ing and analysis.⁴⁸ 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.⁴⁹ The empirical survey methodology for this study was a 4-point scale that included the responses "strongly agree," "agree," "disagree," or "strongly disagree," as did the seed study.⁵⁰

The original intent was to survey 100 respondents in each of the 30 municipalities chosen, resulting in 3,000 observations. Grenville, New Mexico, though the largest municipality in Grid 19, had a population of 25,⁵¹ and was considered entirely too small to meet the originally set 100 respondents per town requirement. To adhere to the original design, Grenville, New Mexico was replaced with Yuma, Colorado (Grid 11, Figure 1, *supra*). 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, which made it particularly interesting to include in the survey.⁵² In addition, Crosbyton, Texas (Grid 28, Figure 1, *supra*), 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 dropped altogether 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 IMPLICATIONS⁵³

Regarding the first preliminary question designed to evaluate interest in state resources and policy, 71% replied yes to this query, and

48. See generally Gary D. Gregory & Michael Di Leo, *Repeated Behavior and Environmental Psychology: The Role of Personal Involvement and Habit Formation in Explaining Water Consumption*, 33 J. APPLIED SOC. PSYCHOL. 1261, 1296 (2003), available at <http://onlinelibrary.wiley.com/doi/10.1111/j.1559-1816.2003.tb01949.x/pdf>; see generally Paul A. Story & Donelson R. Forsyth, *Watershed Conservation and Preservation: Environmental Engagement as Helping Behavior*, 28 J. ENVTL. PSYCHOL. 305, 317 (2008).

49. JUDITH BELL, *DOING YOUR RESEARCH PROJECT: A GUIDE FOR FIRST-TIME RESEARCHERS IN EDUCATION, HEALTH AND SOCIAL SCIENCE* 186 (3rd ed. 1999).

50. Pumphrey et al., *supra* note 1.

51. *American FactFinder*, U.S. CENSUS BUREAU, http://factfinder2.census.gov/faces/tableservices/jsf/pages/productview.xhtml?_afpt=table (last visited Mar. 4, 2012).

52. NORTHEASTERN COLORADO ECON. DEVELOPMENT CORPORATION, *Yuma County Colorado*, NORTHEASTERN COLORADO, available at <http://www.northeasterncolorado.com/html/counties/yuma.php> (last visited Mar. 4, 2012).

53. See *infra* Tables 1–4 in Appendix 2 for the results of this survey in raw data. Table 1 lists the results from the questions of interest regarding municipal water policy; Table 2 lists results from a more refined set of pricing questions; Tables 3 and 4 list results from the

just over 24% responded no; the remainder either refused to answer or did not know whether they would be living in their state more than 20 years.⁵⁴ In other words, about 71% of those surveyed should have a vested interest in state resources and policy.

The response choices for the second preliminary question were on a five-point scale with one being not at all important and five being very important. Only 3.4% responded with a one or two 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 three, indicating indifference to the importance of water conservation. However, 88.1% responded with at least a four on this scale, and almost 72% responded with a level five. Therefore, over 88% indicated that water conservation should be an important issue concerning their local government, and about three-quarters thought this issue was 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 received to the remainder of the survey questions were “thoughtful” responses.

For a more parsimonious exposition of the four-point Likert scale of responses, in Table 1 we combine “strongly agree” and “strongly disagree” responses into either “agree” or “disagree” respectively.⁵⁵ 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 responses in the Indifferent column 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. The right-hand column is probably the most controversial as it lists the overall inference *we* draw from

questions regarding the respondents’ attitudes toward the agricultural and ethanol communities.

54. 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.

55. See *infra* Table 1, Appendix 2.

the results in the other columns about prevailing attitudes across this region. This inference will be based upon the numbers (from the total number of communities) in the Agree, Disagree, or Indifferent columns, relative to the other two outcomes.

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 communities of Alliance and North Platte, Nebraska, Goodland, Kansas, Melrose, New Mexico, and Pampa, Texas, 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, responses to questions three and four indicated this would be a costly approach. The results from question three 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 seven other communities are split on this opinion. Cheyenne, Wyoming, is the only area in which a majority of surveyed residents responded that many in their community would not ignore mandatory restrictions. Again, and as with many of the outcomes outlined in the remainder of this article, 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 the need for substantial oversight and enforcement. On the bright side, the responses to question four indicate that respondents in 24 communities agree with the ability of their prescribed agencies to enforce said policies, while the other five are split on this issue.

Questions five and six are meant to capture opinions of pricing and regulatory policy on a more permanent schedule by essentially re-asking questions one and two, 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. While the message from the responses of question five is clear enough, the message from question six seems more complicated.

We interpret the response to question six as indicative of respondents observing significant water waste already occurring in their com-

munity. 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 six 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 seven 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 waste continues.

As with many communities across the United States, the water charges of a typical household are likely to be the lowest of its household bills. Electricity bills typically have amounts five times that of the water bill;⁵⁶ even monthly cable television⁵⁷ and cellphone charges⁵⁸ are on average three times larger than a household’s water charges.

The USGS estimates that the typical person will use anywhere between 80 to 100 gallons of water each day.⁵⁹ Using a 90 gallon 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.).⁶⁰ 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 \$23.06.⁶¹ In Garden City, Kansas, a typical consumer’s monthly bill would be about \$24.56.⁶² Therefore,

56. *Independent Statistics and Analysis : Electricity*, U.S. ENERGY INFO. ADMIN., <http://www.eia.gov/electricity/data.cfm#sales>.

57. Todd Spangler, *Study: Average Cable TV Bill Is \$71 Per Month*, MULTICHANNEL NEWS (Apr. 16, 2009, 11:59 AM), http://www.multichannel.com/article/196364-Study_Average_Cable_TV_Bill_Is_71_Per_Month.php.

58. *JD Power Analyzes Average Cell Phone Bill*, WIREFLY (Aug. 5, 2008) http://www.wirefly.com/learn/wireless_news/jd-power-analyzes-average-cell-phone-bill.

59. *Water Questions and Answers*, U.S. GEOLOGICAL SURVEY, <http://ga.water.usgs.gov/edu/qa-home-percapita.html> (last updated Nov. 7, 2011, 8:17 PM).

60. *Id.*

61. Personal communication; Water rates from Amber, City of Dalhart, City Hall (4/28/09).

62. GARDEN CITY, KAN., CODE OF ORDINANCES CH. 90 ART. IV(II) (2011), available at http://library.municode.com/HTML/16363/level4/CD_ORD_CH90UT_ARTIVWASE_SDIWA.html#CD_ORD_CH90UT_ARTIVWASE_SDIWA_S90-177WARA (last visited Mar. 4, 2012).

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 lists the responses from questions eight and nine.⁶³ The percentage price increases are as 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 seven in Table 1 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. Only about one-half of those in the remaining communities would reduce their consumption. Exactly what level of price increase would be effective?

According to the results for question eight, a 25% increase would affect about 39% of 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. Roughly 26% of the population claimed 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 intriguing, however, are the responses to question eight combined with inferences drawn from the responses to question nine.

For question nine, roughly 41% of respondents believed 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.

63. See *infra* Table 2, Appendix 2.

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 encourage 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 is important to investigate the respondent's attitudes toward what may be conceived as the cause of the groundwater shortages—the agriculture and ethanol sectors. The analysis 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 what is 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, the consensus may be that the onus of water conservation actually stands with the farmer and ethanol plants, and not with 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.

Table 3 lists the descriptive results for two questions that try to measure area dependence on these sectors.⁶⁴ What we find from questions 10 and 11 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 4 lists the results of questions 12–15 in the same fashion as Table 1.⁶⁵ Interestingly, even though these communities are highly dependent on these sectors, they also firmly believe that these industries

64. See *infra* Table 3, Appendix 2.

65. See *infra* Table 4, Appendix 2.

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 believe that ethanol producers should not be subsidized for any of the water they use, and hence should pay for all of it. And with regard to the farming outcome, when we rephrases 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 gave *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 three communities are indifferent to such a proposal.

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 that consumers in this area are 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 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.⁶⁶ 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—at the taxpayer's 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,⁶⁷ causing the quality to decline for the farmer, the biorefinery, and the municipality. Therefore, the average consumer should be aware that losses from water scarcity will eventually exceed the potential cost of constraining the agricultural and biofuels sectors and the resulting potential reductions in income.

66. JOHN OPIE, *OGALLALA: WATER FOR A DRY LAND* 9 (2000).

67. U.S. GEOLOGICAL SURVEY CIRCULAR 1186, 59 (1999), available at <http://pubs.usgs.gov/circ/circ1186/> (last visited Mar. 4, 2012).

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 inexorably result from 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 that 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, therefore, willing to risk a future loss in exchange for a quicker economic recovery in the present. Whatever the reasons, changes cannot be made without political will, which in turn depends critically on societal attitudes in this region.

APPENDIX 1Preliminary Question Set

- (i) Do you think you will be living in [this state] 20 years from now?
- (ii) How important should water conservation be to [your city's] local government?

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

Question Set 2

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.

Question Set 3

10. How important do you think the agricultural industry is to your city?
11. How important do you think the ethanol industry is to your city?

Question Set 4

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.

APPENDIX 2

TABLE 1: Totals for Questions 1–7

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
7	2910	100.3	16	0	13	Agree/Indiff

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.

TABLE 2: Totals for Questions 8–9

Question #	Total n	Mean n	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
Question #	Total n	Mean n	25% Price Increase	50% Price Increase	75% Price Increase	100% Price Increase	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 questions 8 and 9, the numbers underneath the price increase percentage headings are the actual percentages of responses for that category.

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.

TABLE 4: Totals for Questions 12–15

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.

